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Barataria Bay model,
A report to the
Freeport Sulpher Company
by William Von Arx

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THE BARATARIA BAY MODEL

A Report to

the

FREEPORT SULPHUR COMPANY

by

William S. von Arx

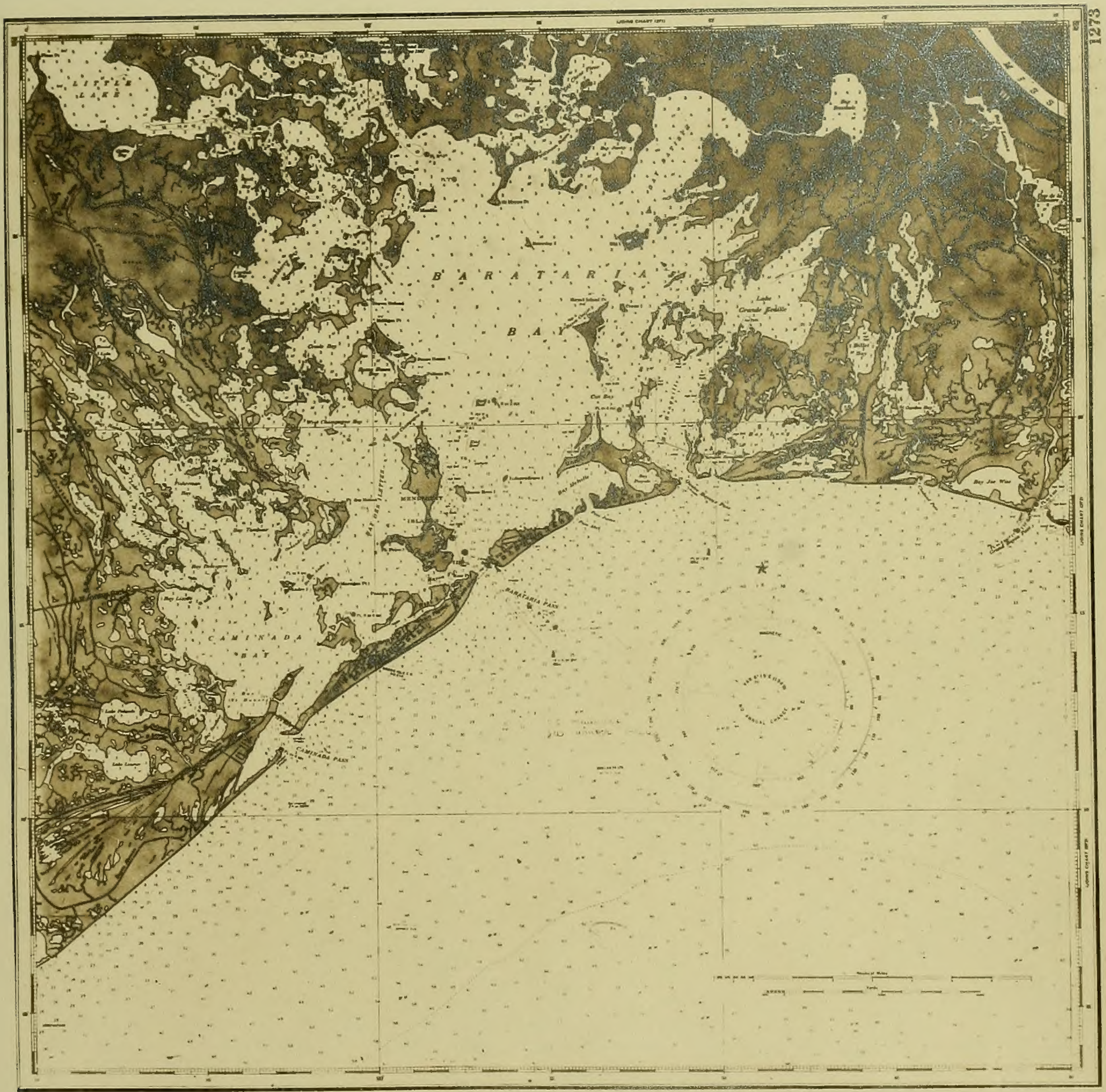
* * *

Woods Hole, Massachusetts

August 1950

COPY NO. 7

Bostwick H. Ketchum



Frontispiece

The area represented by the Barataria Bay model.

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V U. S. Weather Bureau reports from Grand Isle, Louisiana station attached to Copy No. 1

I. SUMMARY - INTRODUCTION

In late December 1948, the Freeport Sulphur Company requested the writer to undertake construction of an hydraulic model of the Barataria Bay area in which their Lake Grande Ecaille, Louisiana, mine is located (see frontispiece adapted from Chart 1273 U.S.C.& G.S.). In this area, roughly 25 miles square, the characteristic depth of water is about three feet, necessitating either a very large model or a highly distorted smaller model. It was decided to make the model eight feet square, and employ a horizontal scale of 1/20,000 and a vertical scale of 1/192; that is, employ a vertical exaggeration of 1/104. The model was built and operated on the property of the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts.

The model was constructed on a strong bed of 2 x 12-inch fir timbers (fig. 1) arranged to form a tight network of triangular voids. The framework was then covered with 3/4 inch marine plywood in steps (fig. 2) so cut that the treads had the shape of the intervals between successive 12-foot contours on the bottom topography in the prototype (fig. 3). This "staircase" was boxed in by a heavy combing, caulked, (fig. 4) and covered with a lath of hardware cloth (fig. 5). Over this a 4-inch thickness (3/4 ton) of Hydrocal B-11 (precision pattern-maker's $CaSO_4$ plaster) was cut as a monolith in which the intricate modeling of the bays and islands could be cut with rotary tools. The layout of the land and islands

was projected from the top of a tower (fig. 6) at a height of 16 feet above the model surface, traced off, (fig. 7), and routed in relief (fig. 8) so that sea level lay 1/4 inch below the land surface. The soundings were then entered on the sea level surface from the same lantern slide and projector, and additional soundings were entered from the original data sheets provided by the U. S. Coast & Geodetic Survey. Soundings were realized by routing between carefully drawn contours (fig. 9). The steps were then blended with hand tools (fig. 10). The resulting surface (fig. 11) is probably accurate to ± 0.015 inch (± 0.25 "foot") vertically and ± 0.03 inch (± 50 "feet") horizontally. Sea level was established as a level plane (± .005-inch) by means of repeated checks with a precise transit on the pair of rails from which the routing tools were suspended.

Gravitational (Froude) scaling of the kinematic ratios of time, velocity and discharge was used unmodified except at the passes connecting the bays with the Gulf of Mexico. In each of the passes the velocity and the turbulence (measured in terms of eddy diffusion) of flow were initially too high. In order to correct this common situation, roughness was artificially increased in the passes by means of wire screens (20 x 20 mesh). Increased roughness in these critical channels not only decreased the velocities so as to agree with the Froude scales but corrected to an acceptable degree the characteristics of channel turbulence as well. To verify the over-all kinematic behavior of

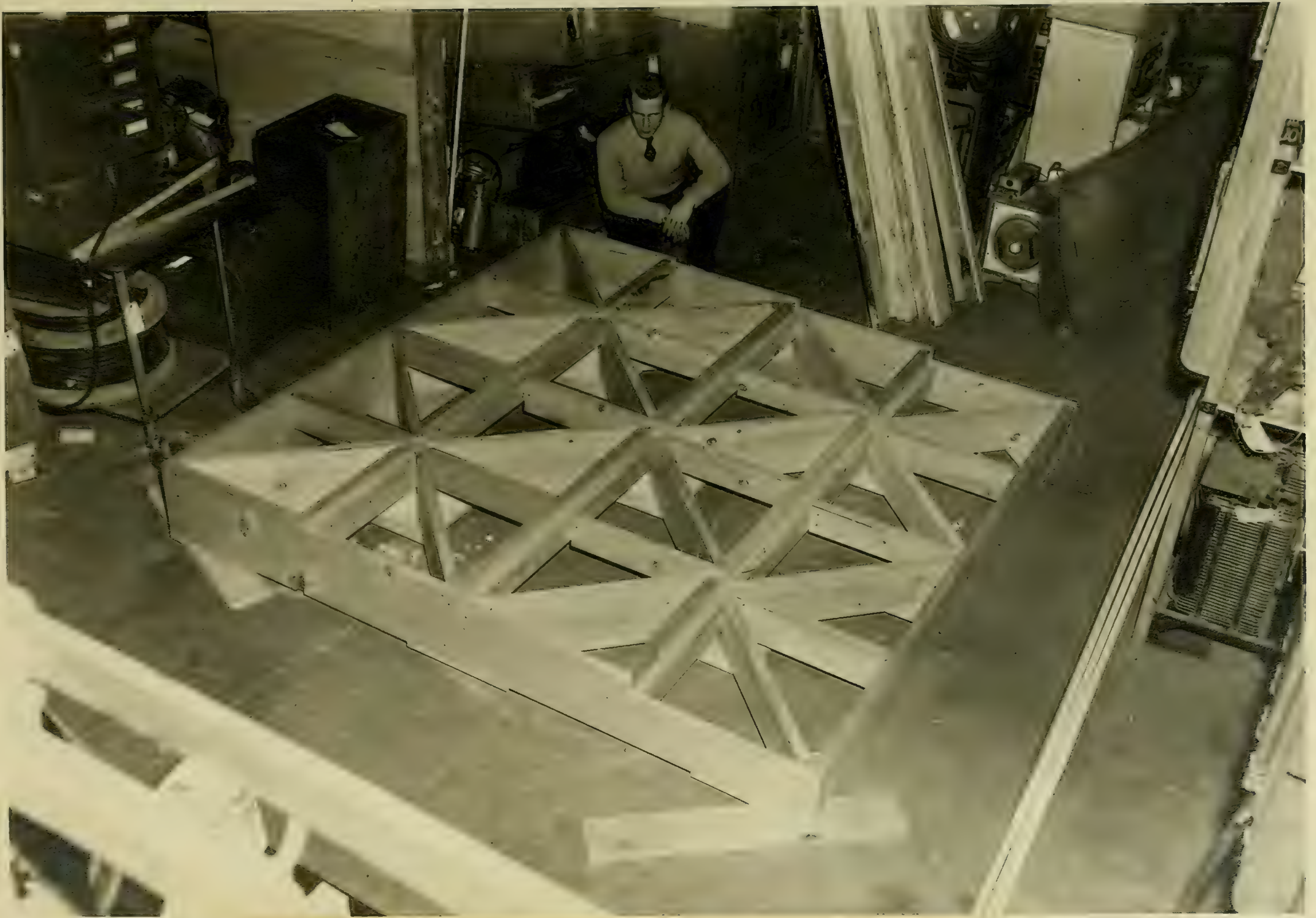

Figure 1. The cellular framework for the Barataria Bay model.

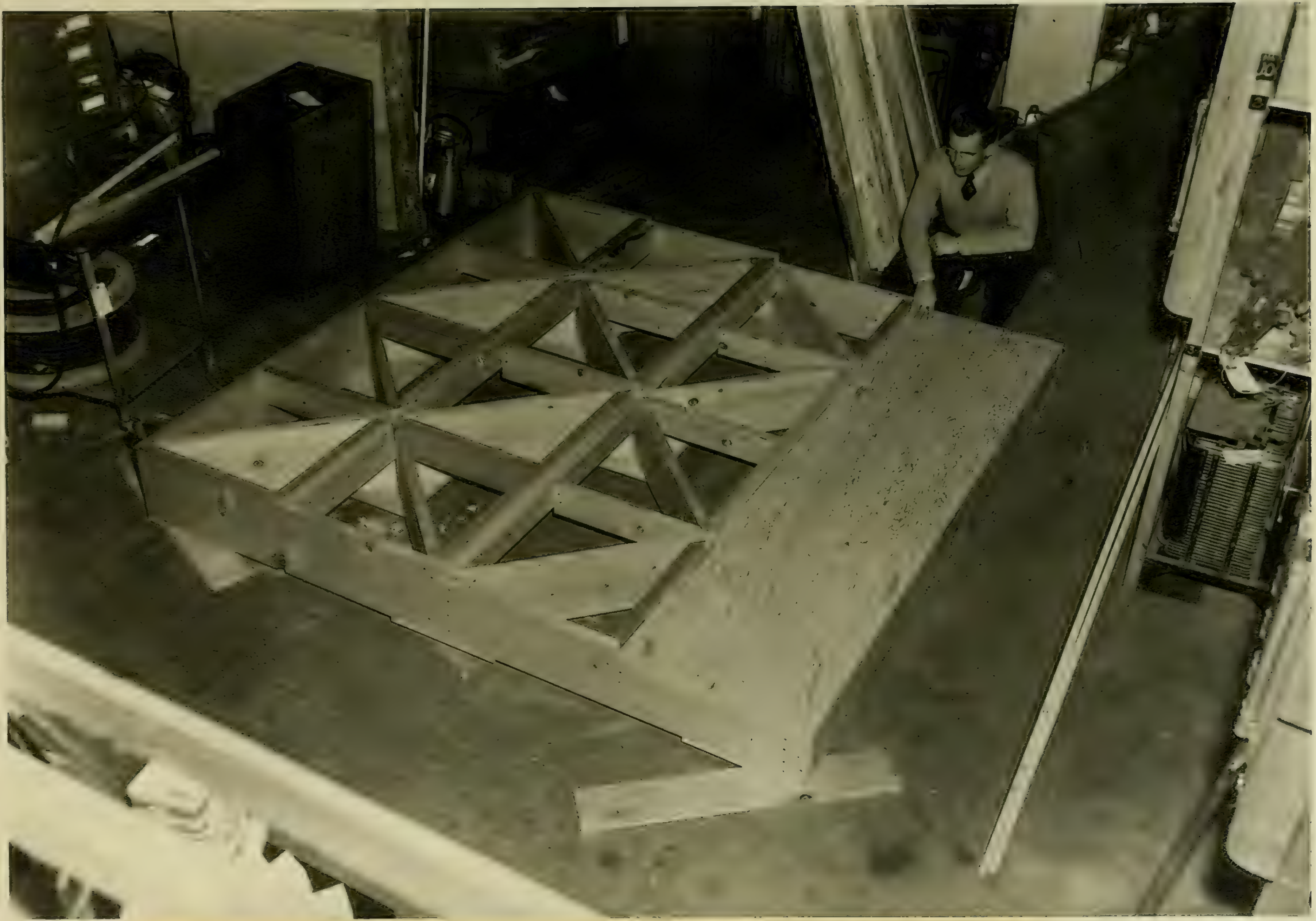

Figure 2. The first of the plywood lifts in the contoured "staircase."

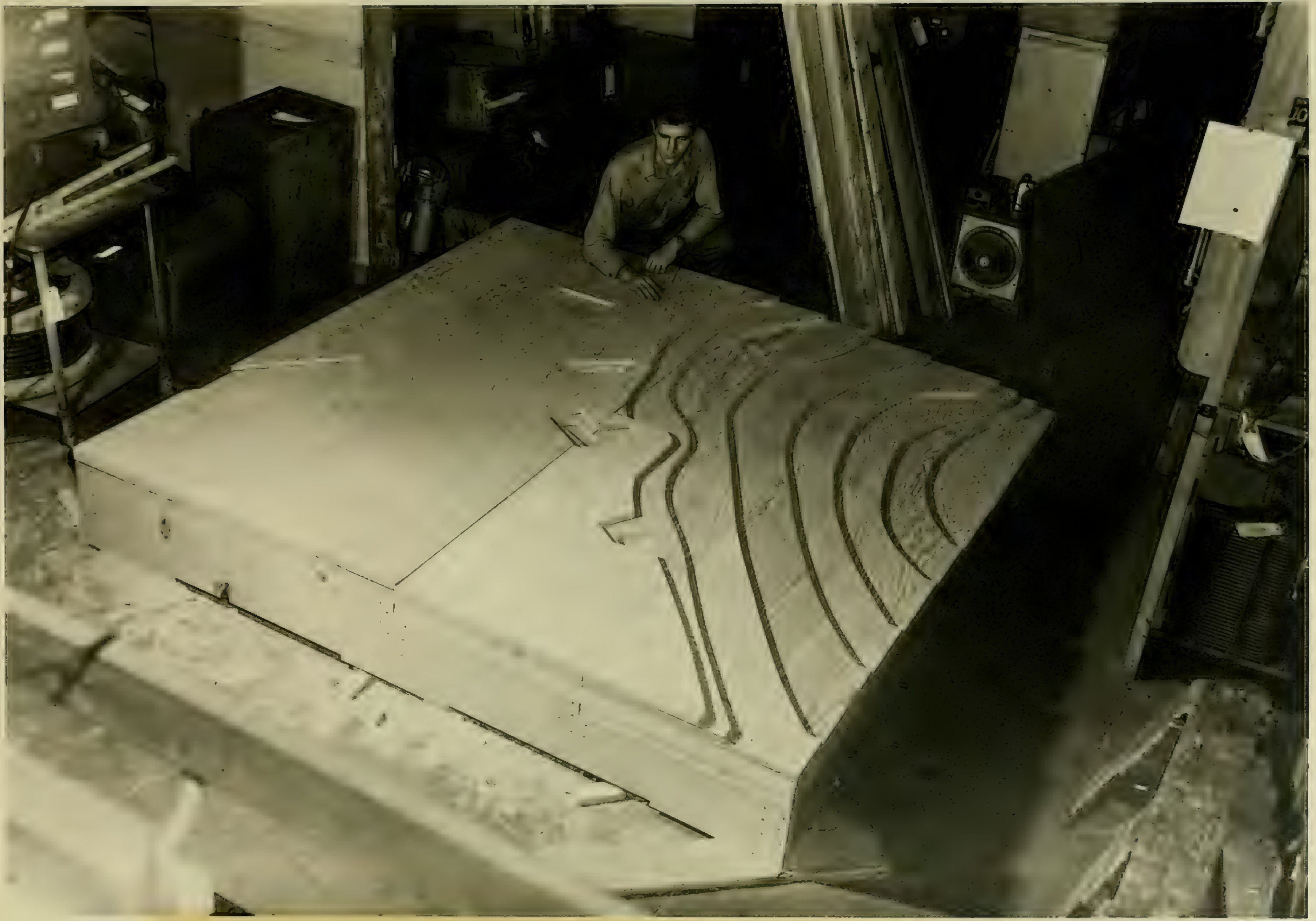

Figure 3. The contour lifts of the Barataria Bay model before nailing.

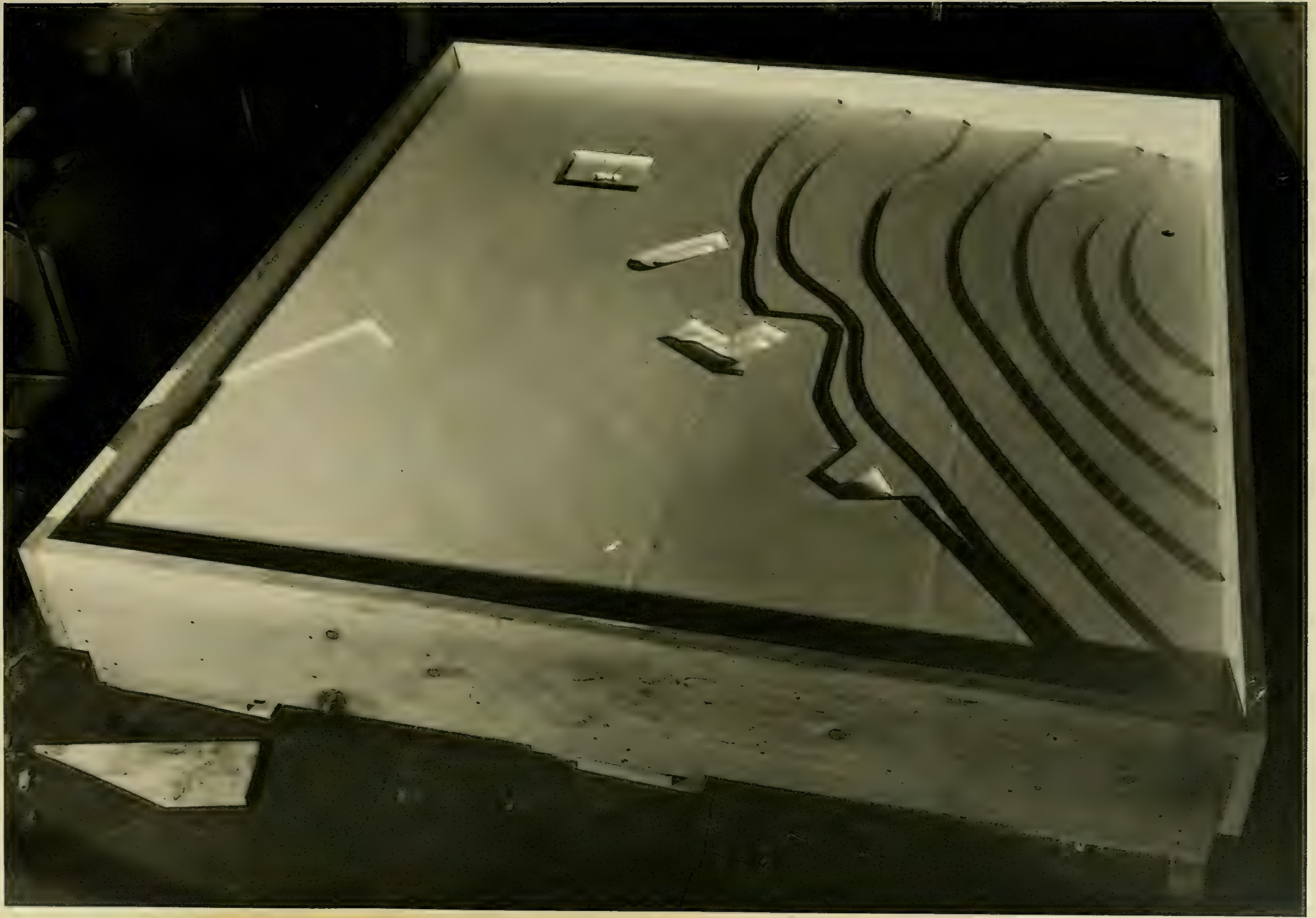

Figure 4. The contour lifts and combing in place and caulked.

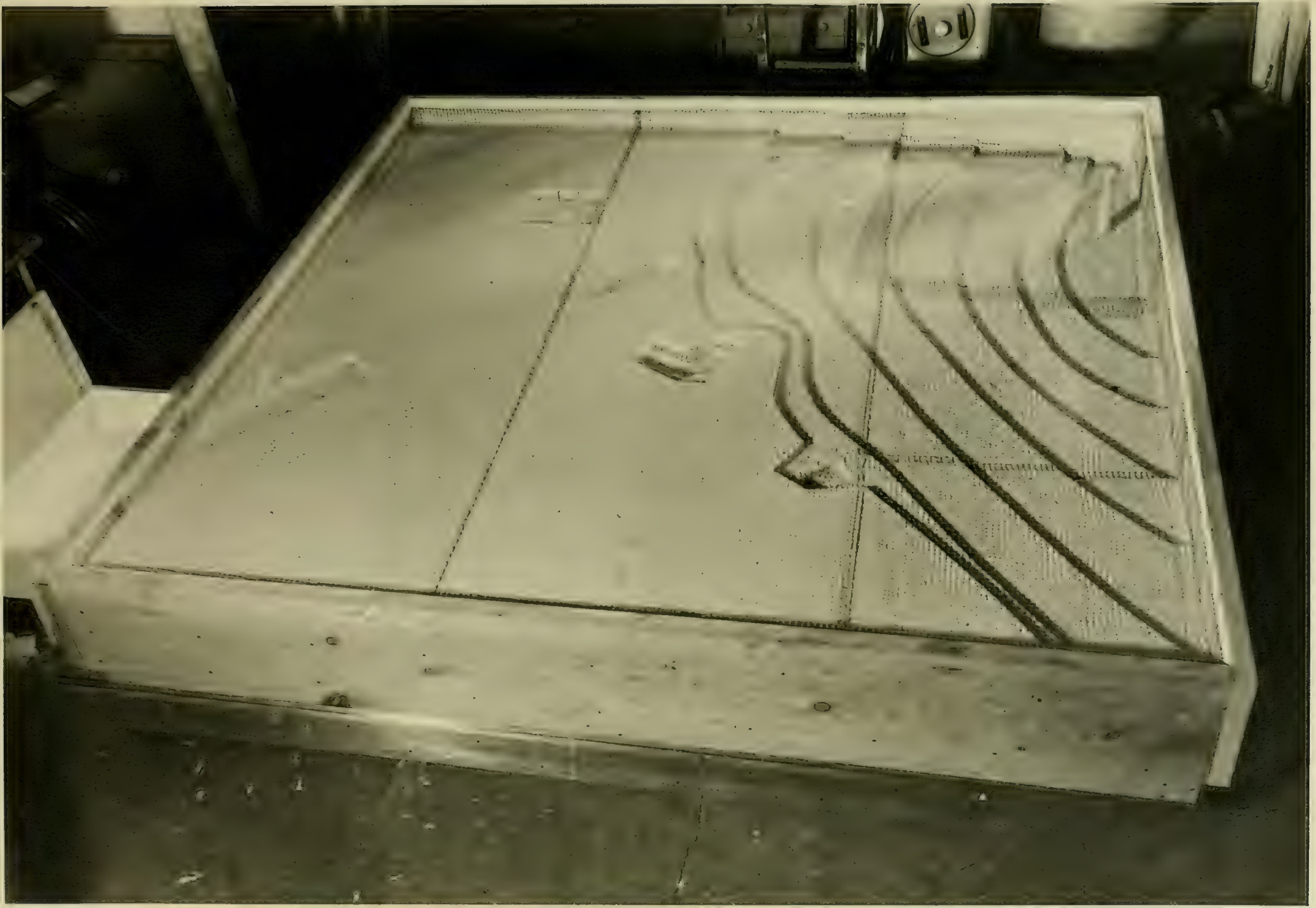

Figure 5. The hardware cloth lath and Little Lake equivalent box in place.

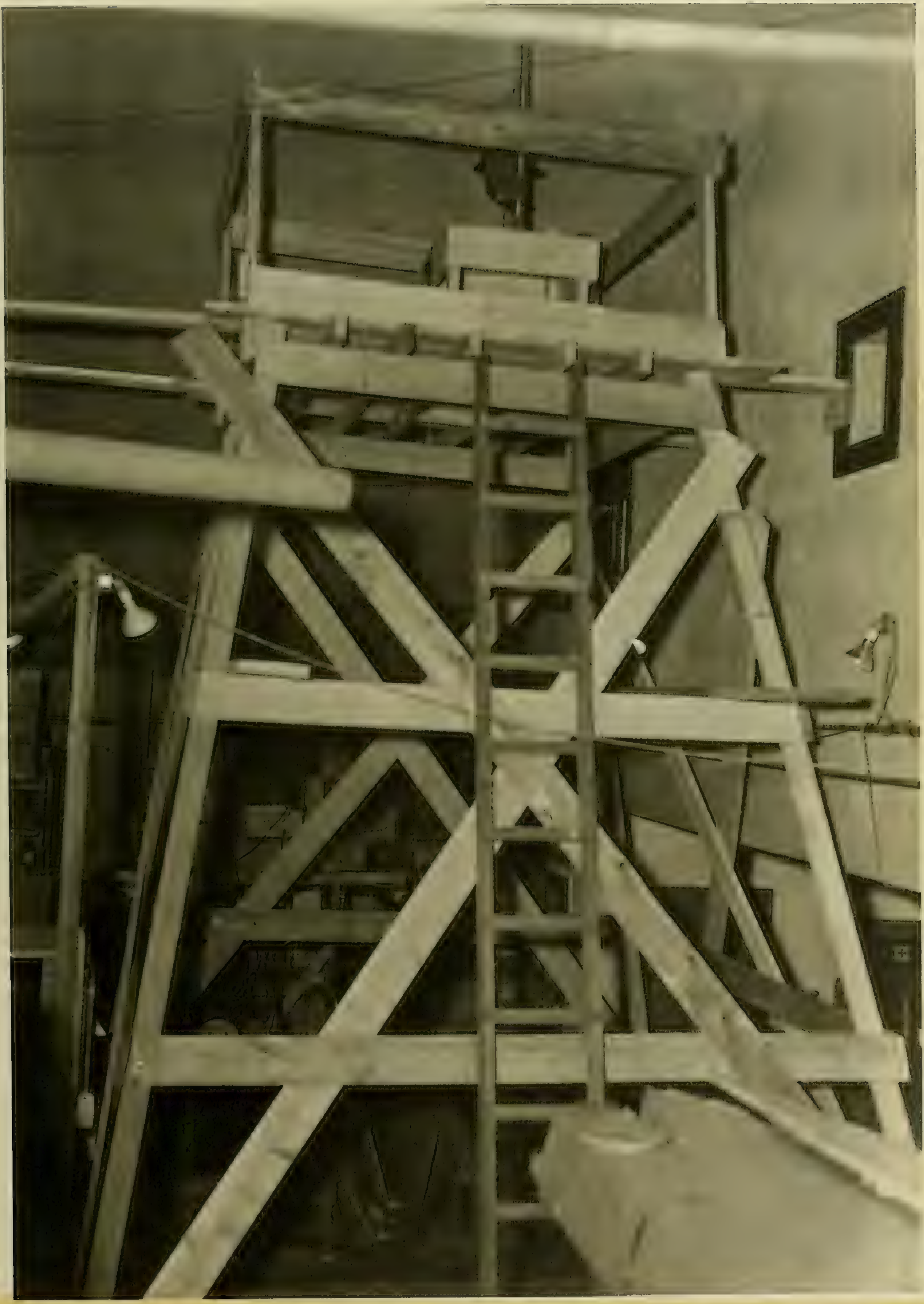

Figure 6. The tower & photographic platform 16 feet above modeled surface.

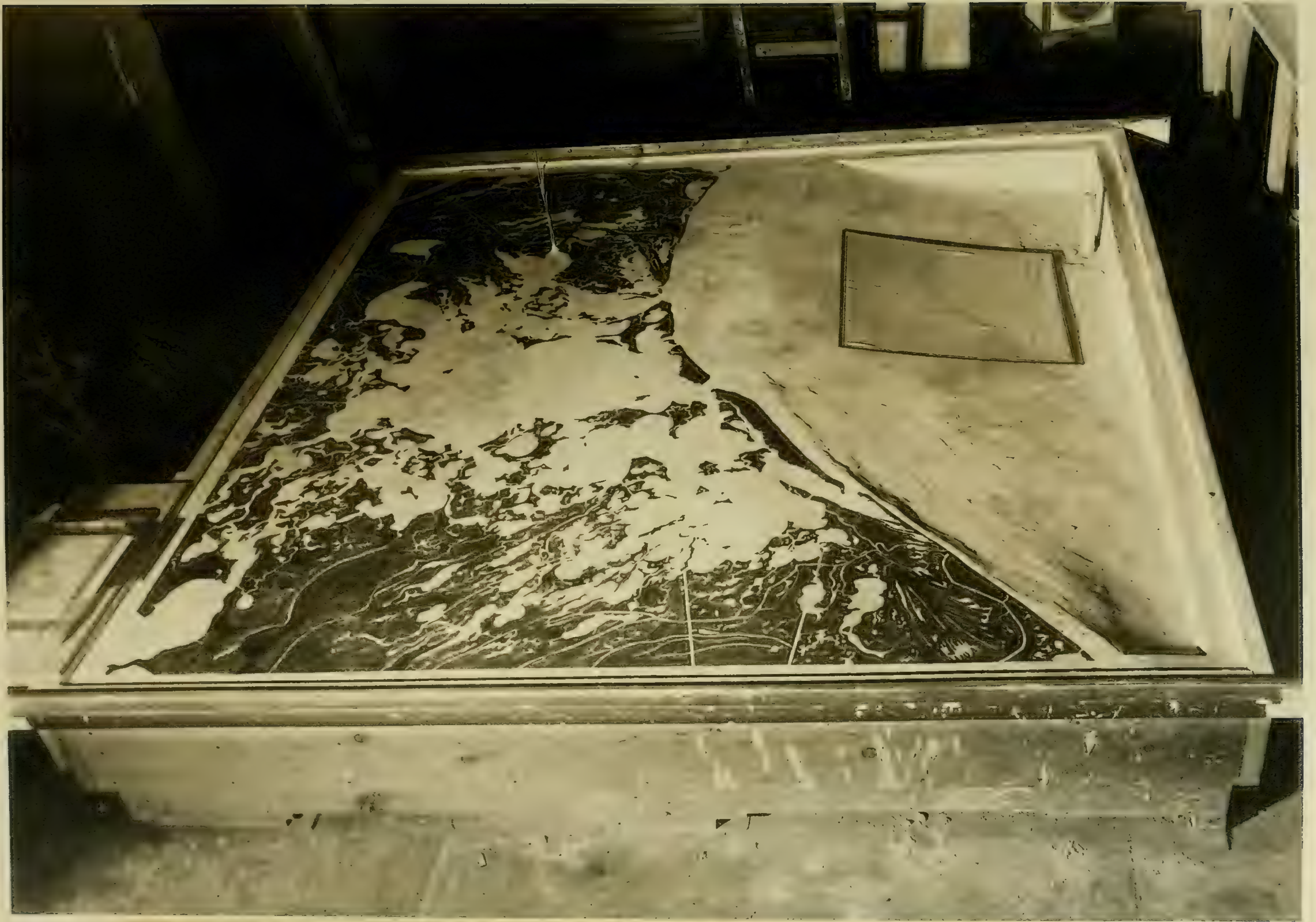

Figure 7. The plaster monolith with the land areas painted on the model surface.

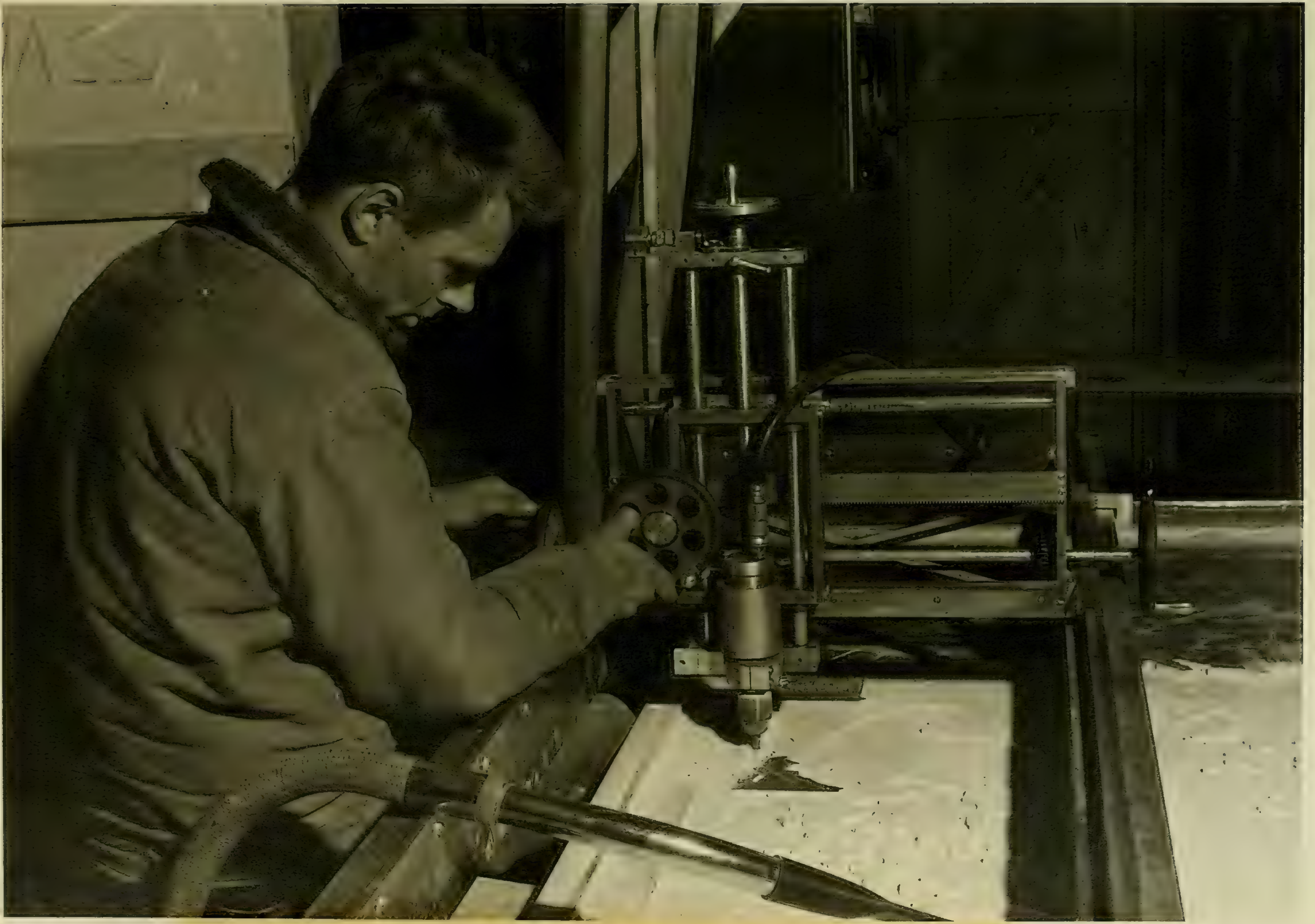

Figure 8. Routing off the land surface to a plane $\frac{1}{4}$-inch above m.s.l.

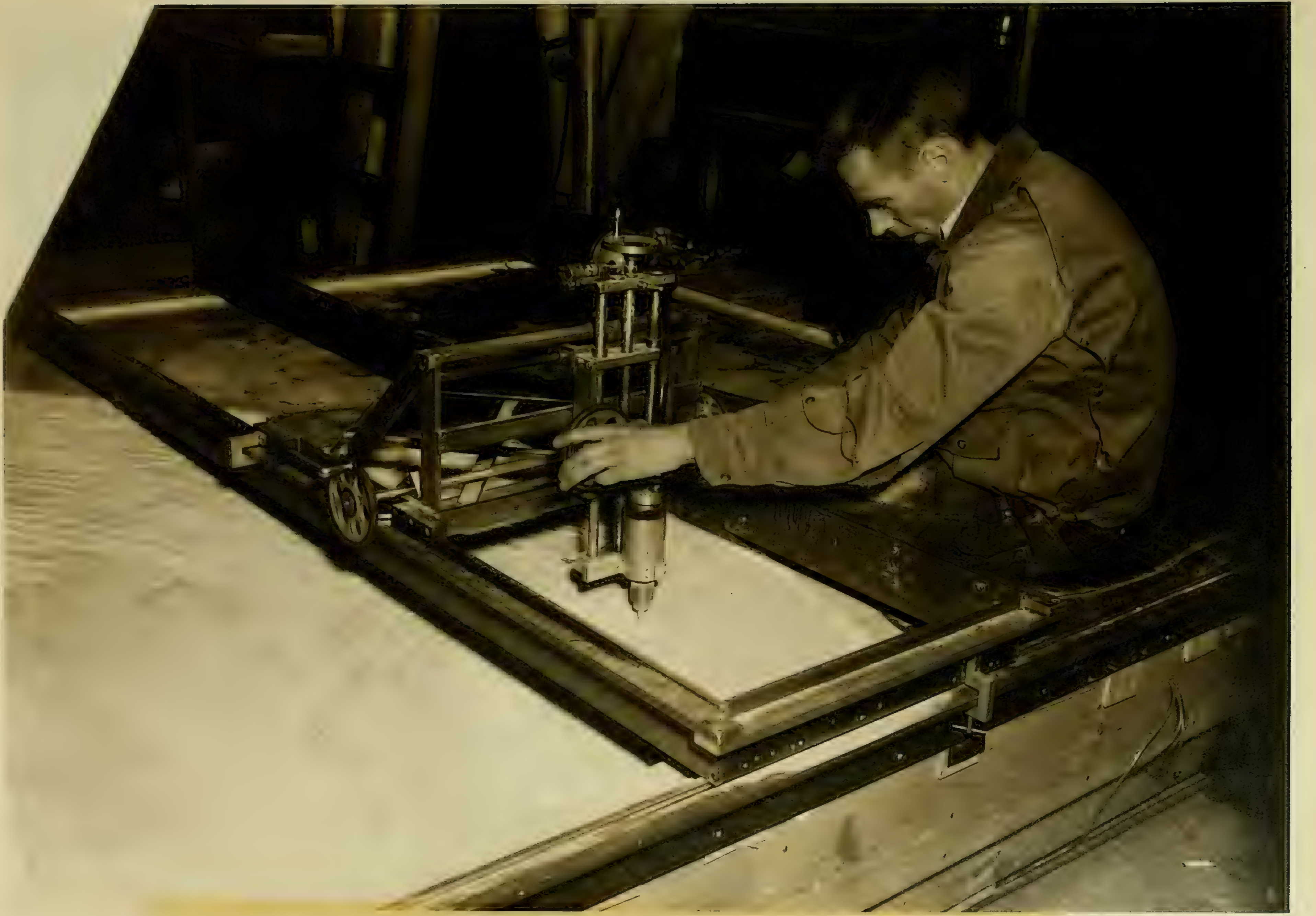

Figure 9. Routing the contours of the Gulf of Mexico portion by 2 foot steps.

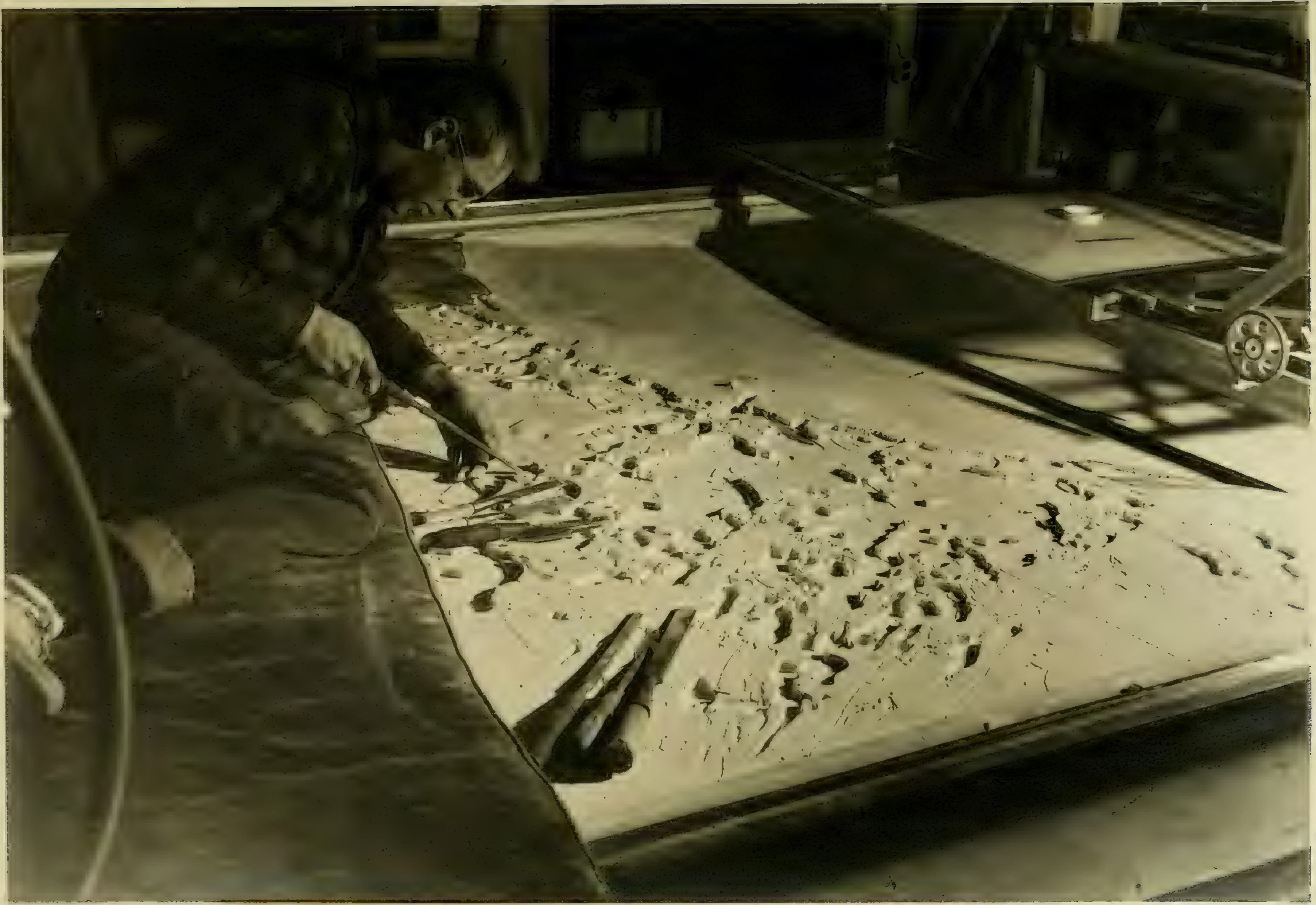

Figure 10. Blending the machined surfaces with hand tools.

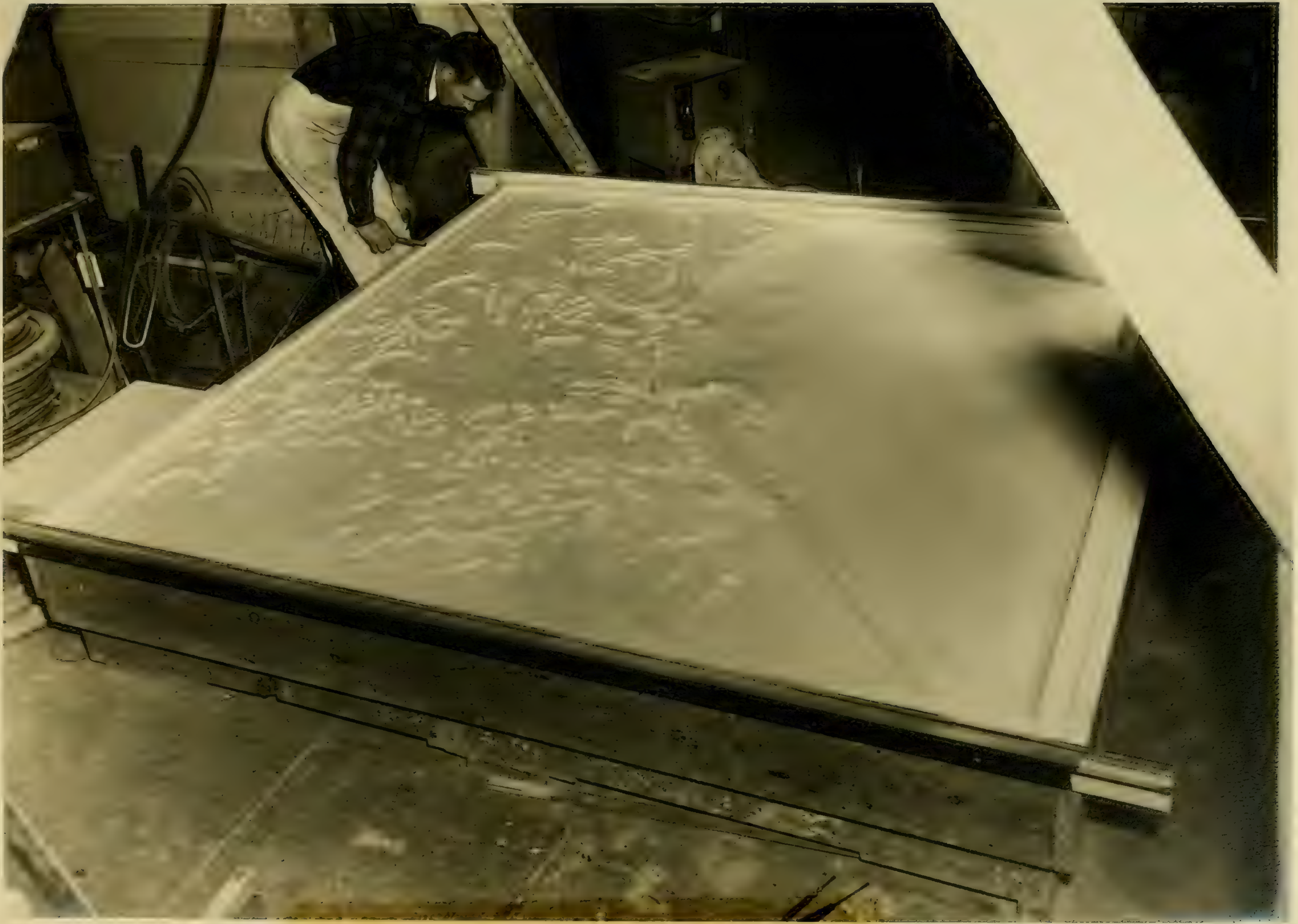

Figure 11. The finished model surface.

the flooded model, as many hydraulic occurrences as possible were compared with data from the detailed field reports of H. A. Marmer,[1] and observations by V. H. Brogdon and the writer. With few adjustments of the model the times of slack water, the occurrence of high and low water, the particle excursions, and magnitudes of velocities were reproduced at a large number of points.

Auxiliary equipment was designed to reproduce tides, winds, rainfall and industrial discharge scaled in accordance with the model constants.

The tide machine was composed of three drums, each of which displaced water and changed sinusoidally the water level in the model at rates in accordance with the time scale 1/1440 (one minute per model "day"). Each drum was driven by a scotch yoke through a stroke of 2 inches; the semi-diurnal drum having a displacement determined by the sum of the amplitudes of the M_2, S_2 and N_2 tidal components and a speed number of the average of the component speed numbers, the first diurnal drum a displacement determined by the amplitude of the O_1 tidal component and a speed number of the O_1 component, and the second diurnal drum a displacement proportional to the sum of the K_1 and P_1 tidal components and driven at the

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1/ The Tide in Barataria Bay, U. S. Coast & Geodetic Survey, Washington, D. C., July 1947.

The Currents in Barataria Bay, U. S. Coast & Geodetic Survey, Washington, D. C., February 1948.

average speed of these two which is precisely a mean solar day per 360°. Thus, the second diurnal drum was run at one cycle per minute and the other two at 30.5 seconds and 64.5 seconds per cycle respectively. This combination produced a succession of great diurnal tides yielding to lesser semi-diurnal tides at intervals of about two "weeks," a progression characteristic of this region of the Gulf of Mexico (fig. 12).

The winds were generated by tank-type vacuum cleaner blowers mounted around the model at the cardinal and intercardinal points. Each was wired to a switch at a central control point and its rate of pumping governed by a Variac. Thus, it was possible to vary the wind speed and direction to reproduce either the detailed or average wind as it occurred during the periods of interest to the sponsors and in accordance with the records of the U. S. Weather Bureau reports from Grand Isle, Louisiana.[2/] Velocity calibration of the wind machines was accomplished by observing the rate at which the surface layer of water in the model was propelled under wind stress at the steady state. It was assumed on the basis of field experience and values derived from empirical equations for wind stress that in more than 10 miles of fetch the stress on the surface is such as to produce an equilibrium surface current speed between 2 to 3% of the wind speed.[3/] By this

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2/ See Appendix V attached to Copy No. 1.

3/ Sverdrup, Johnson & Fleming, The Oceans, Prentice Hall, New York, 1942, pp. 489-503.

measure, it was possible to produce winds of hurricane force (100 "knots") from the simultaneous draught of three blowers running at full speed. Due to the small horizontal scale and the vertical exaggeration of the model, the capillary wave height was too small and the capillary wave length was too large for wave action to be in scale or to produce the significant mixing effects found in nature.

Rainfall, which amounts to 60 inches per year on a watershed of some 1100 square miles to the north of the modeled area, drains through the modeled area at the rate of approximately 450,000,000 cubic feet per day, according to Marmer.4/ This flow was introduced in the Little Lake equivalent box at the northwest end of the model by means of a pump attached to the tide machine. This pump drew water from the Gulf and produced both a closed circulation system for the rainfall, and a current of water through a venturi which generated a slow longshore current moving westward along the coast in agreement with known offshore circulation.

Industrial wastes (also referred to as bleed water) were introduced into the model through copper tubes embedded in the plaster and terminated at their proper geographical positions on the Freeport Sulphur Company properties. The injection ends of the tubes were attached to open glass cups at the level of the water in the model.

4/ The rainfall on the modeled area was disregarded.

Each cup was supplied at first by a calibrated dropper and later on by the outlet of a proportioning funnel, both of which in turn being fed by a 100 cc hypodermic syringe acting as a positive displacement pump closed by a motor-driven screw. Thus, it was possible to know and control the quantities of industrial waste being introduced into the model either by counting drops delivered per minute from calibrated dropper tips or by timing the revolutions of the motor-driven screw. The industrial waste was simulated by an acid. The acid concentration chosen was such that when it mixed with a given number of volumes of ambient model water, containing an indicator solution of brom cresol green, it changed color from yellow to blue. The model water was set chemically to a known alkaline state (blue) such that for a given acid strength the color change (yellow-blue) would occur at a predetermined dilution. In this way the industrial waste, more concentrated than any specified dilution figure was represented by yellow water, and further dilutions in excess of those specified by a pleasing blue color which pervaded the whole model and varied in intensity with the depth of water.

Under certain conditions, continued discharge of industrial waste eventually extended unneutralized acid boundaries into the Gulf portion of the model. If routine titration of samples of water drawn from the Gulf showed it necessary, as the unneutralized acid reached and mixed away in the Gulf, a base of identical strength was introduced volume for volume into the Gulf at the

circulating venturi. In this way the ambient water in the Gulf volume was rendered chemically infinite and was maintained quantitatively in its alkaline condition. Thus the model could be run indefinitely to study the steady states of waste distribution in the bays under a variety of controlled conditions.

The results of the model studies were recorded automatically in color photographs made simultaneously with each of two cameras (1) a 35 mm Graflex pneumatic microfilming camera operated once every 7.5 seconds producing 8 exposures per model "day" and (2) a 16 mm Bolex time-lapse motion-picture camera operated electrically at 1 exposure every second yielding 60 exposures per model "day" and effecting a contraction of time, when projected at 16 frames per second, of 1/23040, that is, of 1 model "day" per 3.75 mean solar seconds. Light for photography was provided by 12 No. 2 photoflood lamps in reflectors, a total of 6000 watts illumination in controllable quantities for uniform lighting. An electric clock fitted with a dial graduated in 24 model "hours" swept by the second hand, 60 "days" indicated by the minute hand, and 24 "months" indicated by the hour hand, was mounted in the field of view of both cameras so that the elapsed time from the beginning of each experiment was automatically indicated and totalized. Similarly the contribution of each of the tide drums was integrated and the sum of their effects indicated by a traveling pointer on a scale large enough for the cameras to record the height of water to 0.05 scale "foot." The same integrator was coupled to a pen

which wrote a record of the tides on a paper tape moving at 1/2 inch per minute (fig. 12, and completely represented in Appendix IV of Copy No. 1 only). The wind direction was indicated by a small banner on a circular card placed on an island (unnamed) near the center of the model. In "no wind" conditions this indicator was removed from the model.

The tests of the model consumed approximately 65,000 model "hours" (about seven and one-half model "years") and were recorded in color on approximately 13,000 frames of 35 mm film strip and 3,000 feet of 16 mm time-lapse motion-picture film. The bulk of this record has been reduced to a series of 41 summary drawings (Appendix III) representing the continuous and intermittent (tidal) excursion of the simulated industrial waste in the model for each wind condition in each of two major bleed water discharge conditions, Tests B and C, and two concentration conditions, nominally 1:1000 and 1:200. Test A, which shows the distribution of fresh water drainage through the model area, is most easily seen in the original 16 mm time-lapse motion picture. However, figure 13 shows a characteristic stage after 30 "days" advance of fresh water into Barataria Bay from the north. This circulation of fresh water drainage undoubtedly tends to block the otherwise free circulation of water from Lake Grande Ecaille into Barataria Bay.

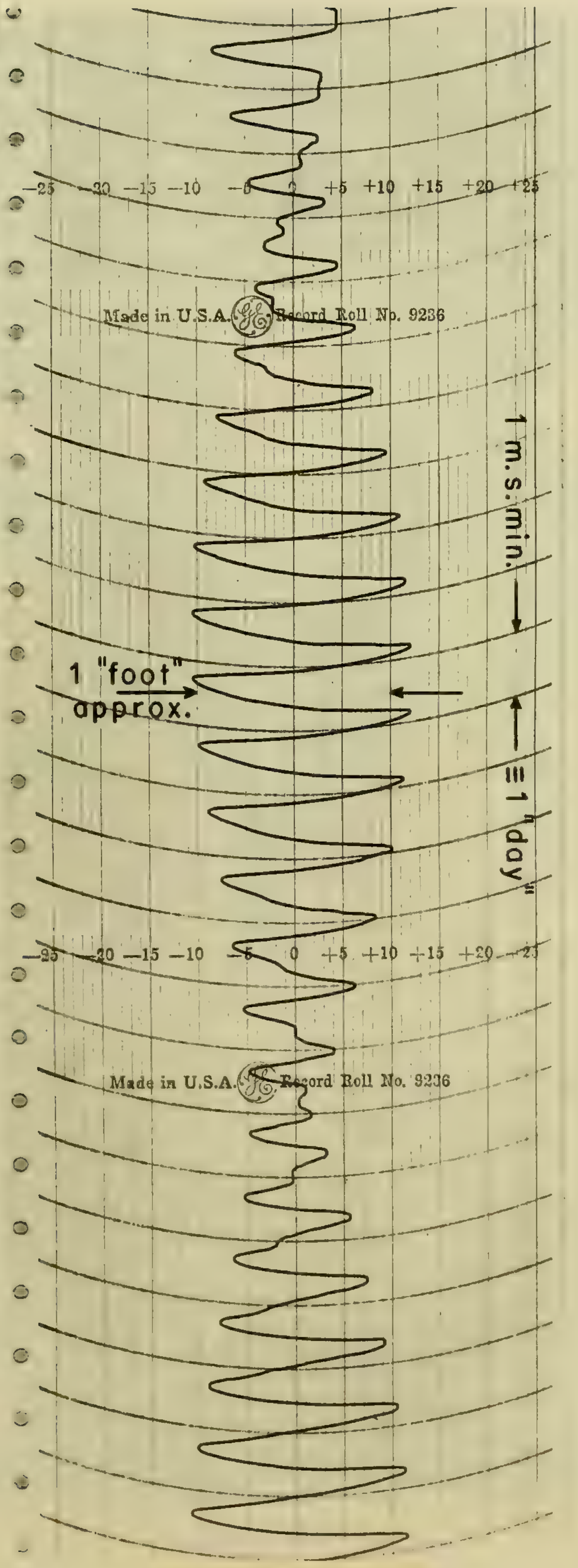

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Figure 12.

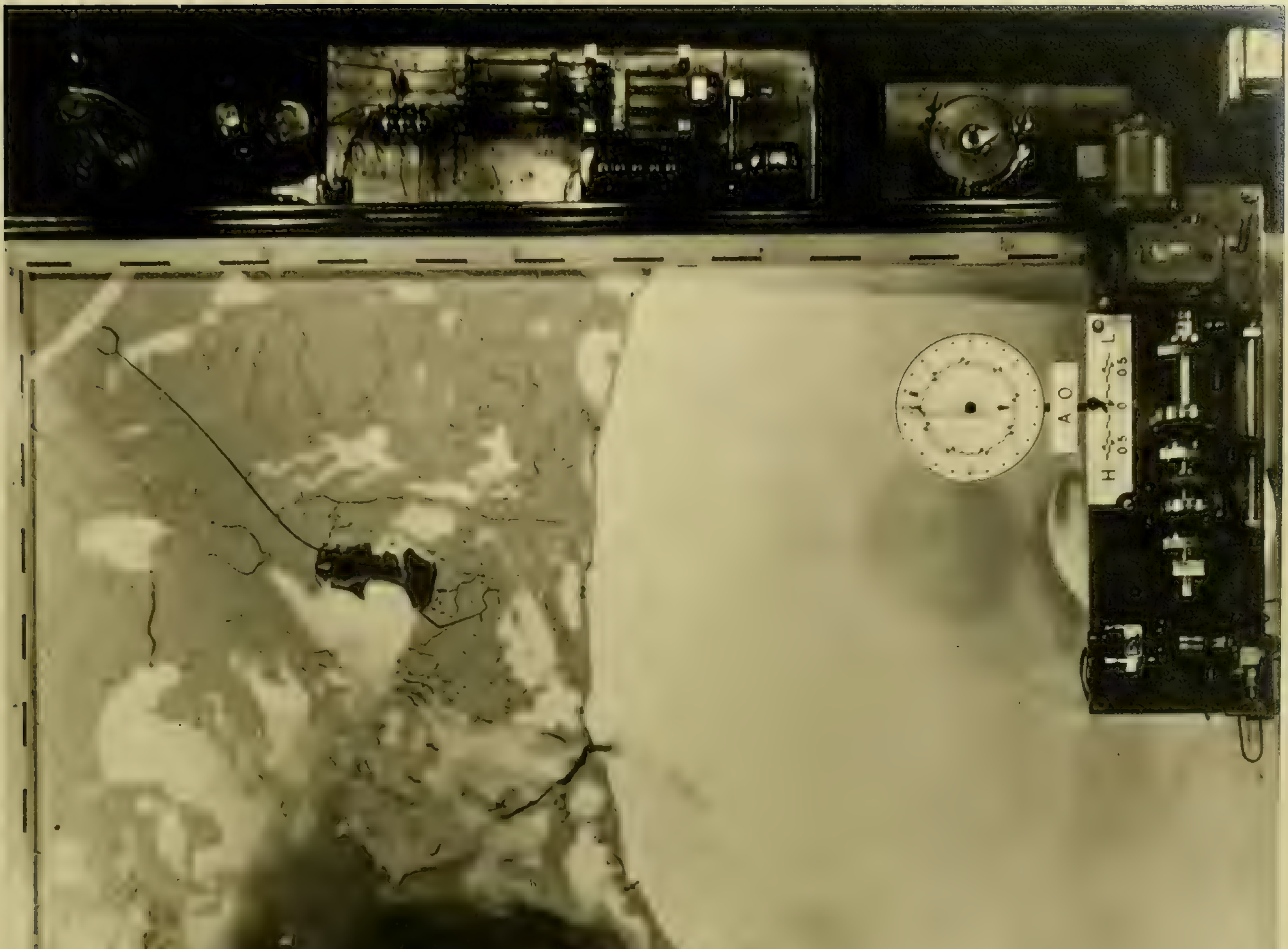

Figure 13.

Test AO after 30 days continuous rainfall discharge.

II. THE ROLE OF MODERN HYDRAULIC MODELS

Hydraulic models as they are understood and employed today are the product of several decades of experimental development. There are no comprehensive mathematical relationships to express the entire range of correspondence between models and their prototypes. Lacking these, the design and operation of hydraulic models is an art and the results obtained are necessarily subject to interpretation. The process of interpretation is frequently qualitative or categorical in the "is" or "is not" sense since a full accounting of all the physical properties of a fluid system is not always possible. Within these limitations, however, the use of models has great interpretive value. Today, most important problems in fluid engineering are solved through combined consideration of model experiments and mathematical analysis of the known physical factors.

The function of a model is essentially that of an analogue computer. When a geometrically extensive or lengthy series of hydraulic events involves a great number of complex factors it is too difficult for the human mind and too laborious for exact mathematical analysis to cope with them all simultaneously. Usually, more intelligible results can be obtained if a similar system is constructed and studied under controlled laboratory conditions.

The degree of similarity between a model and its prototype

may be only geometrical, or it may be kinematic, or dynamic. Two structures are said to be geometrically similar if the ratios of all homologous dimensions are equal. Kinematic similarity is similarity of motion. The motions of kinematically similar systems are geometrically similar and the ratios of the velocities of the several homologous particles in motion are equal. Few models are similar to a higher degree. It is possible, however, for two systems to possess dynamic similarity either in certain or all respects. In order to achieve dynamic similarity the two systems must be kinematically similar and in addition the ratios of the homologous masses and forces concerned in the motion must be equal. The condition of complete dynamic similarity is seldom achieved except in instances where the model is identical with the prototype in every respect.

III. THE SCALES OF THE BARATARIA BAY MODEL

The scales of the Barataria Bay model are based primarily on the equations of kinematic similarity due to Froude. These equations concern the relationships between gravitationally energized fluid systems in a state of continuous quasi-hydrostatic equilibrium. In an estuary like Barataria Bay there are two dominantly gravitational factors controlling the circulation; the tides and the drainage of rainfall. Wind stress is also present and scaled to the model since it produces very significant water motions, but since this force is not gravitational its scaling transcends kinematic relationships.

Once the similarity of circulation in the main bodies of water is established in a model it is possible to introduce an indicator to trace the progress of suitably scaled quantities of industrial discharge under a variety of simulated natural conditions. This was the purpose for which the Barataria Bay model was built.

The notation used in scaling relationships is similar to ordinary physical notation except that all symbols that apply to the prototype are followed by a subscript "p" and those applying to the model are followed by a subscript "m." Scaling ratios are usually dimensionless and followed by a subscript "r" defined for any quantity J as

$$J_r = \frac{J_m}{J_p} . \qquad (1)$$

It is possible to assign J_m unit value and express J_p as its multiple. Thus the time scale in a model compressing the events of one mean solar day within the compass of one mean solar minute; $T_r = T_m/T_p = 1/1440$. The units of the ratio cancel mathematically but if they are preserved the scaling ratio expresses, instance for instance, the proportion in common units of the homologous quantity in either the model or the prototype. In the case illustrated one may justly speak and think interpretatively of a model "day" but this interval is still only one mean solar minute for purposes of calculation.

Choice of the vertical and horizontal scales was determined for the Barataria Bay model by the dimensions of the available space, the vertical distortion required to maintain a useful depth of water and by the rate of going of the model. Because of the complexity of the water-land areas in the Barataria Bay region it was considered imprudent to build the model on a horizontal scale smaller than 1/20,000. This horizontal scale allows all the area of interest to the sponsors and the additional areas containing significant influences of oceanographic and hydrologic kinds, except part of Little Lake, to be included in a space eight by eight feet. The remainder of Little Lake was represented by a box of equivalent area mounted on the outside of the model at

the northwest corner and connected to the fluid system by a tunnel of suitable dimensions. The horizontal scale being thus fixed, and considering the desirability of a time scale of one mean solar minute per mean solar day, the vertical scale was calculated from the kinematic formula of Froude for the distorted open channel model in which the value of g and properties of water are substantially the same for the model and the prototype.

$$y_r = \left(\frac{L_r}{T_r}\right)^2 = \frac{1}{193} \qquad (2)$$

This vertical scale is within half of one per cent of 1/16 inch per "foot" and was so adopted. The resulting vertical distortion is

$$D_v = \frac{L_r}{y_r} = \frac{192}{20,000} = \frac{1}{104} \qquad (3)$$

This amount of vertical distortion is acceptable.

The Froude velocity scale is derived from consideration of the rate of progress of a gravity wave of very great length compared with the depth of water; that is of tidal dimensions. The rate of progress of such a wave is given by $\sqrt{g\ d}$, where g is the acceleration of gravity and d is the depth of water. The acceleration of gravity is substantially the same in both the model and prototype hence the velocity ratio is entirely controlled by the

square root of the vertical scale, $\sqrt{y_r}$. Thus

$$V_r = \sqrt{y_r} \doteq 1/13.9 \tag{4}$$

This means that a velocity of 1 knot in the prototype is represented in the model by a velocity of 1/13.9 knot or 3.65 cm/sec. Since the available data on the velocities of flow in the prototype were given in knots, a ruler was constructed and graduated in 3.65 cm intervals with tenths on one side and quarters on the other so that the velocities in the model might be checked with these lengths against the seconds beat of a break-circuit chronometer made audible through a loud speaker.

With the establishment of the time and length scales it was possible to calculate the discharge scale for the rainwater and bleed water. The kinematic discharge of rivers and industrial waste is scaled with regard to volume $\left[(L_r)^2\ y_r\right]$ per unit time (T_r). Since $T_r = L_r/\sqrt{y_r}$ the total discharge scale Q_r is

$$Q_r = \frac{(L_r)^2\ y_r}{\left(\dfrac{L_r}{\sqrt{y_r}}\right)} = L_r(y_r)^{3/2} = \frac{1}{5.3 \times 10^7} \tag{5}$$

The discharge $Q_m = Q_r Q_p$ is the discharge into the model over the same interval of time as is expressed for the discharge in the prototype. To make this perfectly clear, if the discharge of a river is (10^n) m^3/mean solar day, the scaled discharge into the river is $Q_r \times 10^n$ m^3/mean solar day, not per model "day."

The characteristic kinematic scaling factors used in the Barataria Bay model construction and operation are as follows:

L_r	horizontal length scale	1/20,000
y_r	vertical length scale	1/192
$D_v = L_r/y_r$	vertical distortion factor	192/20,000 = 1/104
$T_r = L_r/\sqrt{y_r}$	time scale	1/1440 = 1 min./"day"
$V_r = \sqrt{y_r}$	velocity scale	1/13.8(3) = 3.65 cm/sec/"kt"
$Q_r = L_r(y_r)^{3/2}$	discharge scale (total)	1/53,000,000
ρ_r	kinematic density scale	1/1
$U_r = 0.025\ V_r$	wind scale	(empirical calibration)

The approximate physical dimensions of the Barataria Bay model are given to provide some acquaintance with the scale of the model experiments. About six months of effort by sixteen part- and full-time craftsmen were required to build the model and its auxiliary equipment.

over-all north-south length of modeled surface	8.0 feet
over-all east-west length of modeled surface	8.0 feet
maximum depth in Gulf portion	0.5 feet
Characteristic depth in Barataria Bay/-Grande Ecaille portion	0.04 foot
height of land above msl.	0.02 foot
material routed away to form modeled surface	600 lbs.
volume of water in system	20 cubic feet
weight of flooded model	2000 lbs.
dimensions of model working space	20 x 20 x 20 feet
volume of model and auxiliary equipment	3000 cubic feet
electric motors (synchronous)	4
electric motors (controllable speed)	12
power consumption (lighting)	6000 watts
power consumption (total mechanical)	7500 watts

IV. RECONCILIATION OF KINEMATIC AND DYNAMIC PROCESSES

The considerations preceding the table of scales have not included the scaling of density and wind velocity. The scaling of density influences mixing, which is essentially a dynamic process, and the scaling of wind velocity involves several considerations which are most accurately reconciled by an empirical process in the present state of the model making art.

Density scales[5]:- The circulation in estuaries frequently involves the mixing of two or more water masses of different density. In direct kinematic (Froude) scaling these density differences should be maintained 1/1 in a model. The 1/1 scale of densities leads to satisfactory results if the problem involves only the kinematics of incursion. If, for instance, a large mass of salt water flows in from the sea under fresh water as in a lagoon or estuary, the velocities, volumes and times of arrival of the main water masses are correct, but the mixing of the two water masses is usually quite dissimilar and unrealistic. The water masses tend to retain their identity too long in the model and to stratify. This result is inevitable, for a fractional scale kinematically similar model can rarely be made to possess a 1/1 ratio of both

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[5] While it is customary to consider density in model theory, it is usually simpler to measure specific gravity with respect to pure water at some standard temperature in experimental work. The specific gravity so measured is numerically equivalent to density.

Froude and Reynolds numbers with its prototype. In the scales of oceanographic models the Reynolds numbers of flow in the model are often several orders of magnitude lower than corresponding values in the prototype.

In the Barataria Bay model two instances of deficient mixing are potentially present due to stratification accompanying (1) the density difference between the predominantly fresh drainage of rainfall into the northwestern part of Barataria Bay via Bayou St. Denis and Grand Bayou, and (2) the density difference between the ambient water of the Barataria Bay-Lake Grande Ecaille system and bleed water. Since there is at present no useful simultaneous solution to the problem of combined Froude and Reynolds density scales a choice was made in the first case in favor of the reciprocal Reynolds scale for increased realism of the circulation, and in the second to abide with the unmodified Froude scale since the injected volumes of bleed water exert a truly insignificant effect on the circulation.

The density difference between fresh water drainage and the ambient density of Barataria Bay water is amply sufficient to cause the fresh water to float on the surface of the ambient water as a thin but very extensive sheet. This tendency exists in nature to the same extent but it is overcome by the mixing processes associated with higher Reynolds numbers of flow, higher eddy diffusivity, and mixing by wave action.. In nature the several mixing processes carry the buoyant fresh water downward

to form a homogeneous vertical mixture and are so vigorous that they also carry bottom silt upward in sufficient quantities to maintain a high degree of turbidity. In order to reproduce these effects in a model it is necessary to reduce the work to be done by the existing turbulence and associated eddy diffusion. The work to be done is lessened by reducing the density difference empirically by an amount roughly equivalent to the vertical distortion. The necessary change of density difference was actually found to be about two orders of magnitude. This factor reduces the initially small density difference (0.012) to such an uncontrollably small magnitude (0.00012) that the desired condition is more reliably represented by a homogeneous system. Thus the small volume (165 cc/min.) required for the rainfall contribution was pumped from the very large Gulf of Mexico volume and piped into the Little Lake equivalent box attached to the northwest corner of the model. This method of closing the rainfall circulation produced less than 1 part in 2000 error in the tidal circulation and automatically maintained a constant mean sea level.

In the second case, that of the bleed water density scaling, the volumes are insignificant compared with the tidal exchange of the waters they enter, and as bleed water is heavier than the ambient water it tends to sink. While bleed water is about as much heavier than the ambient water per unit volume as the rain water is lighter, and could also be well approximated by a homogeneous fluid, it was considered a more conservative approach if

the 1/1 density differences indicated by Froude scaling were maintained.[6/] This decision causes the simulated bleed water of the model to stratify and collect in depressions and practically to fill these depressions before traveling farther along. It also exaggerates the concentrations of bleed water by retarding its rate of mixing with the ambient water which would otherwise allow it to be carried away with greater rapidity and at greater dilution than the model indicates. When at length, under one-to-one density scaling conditions, the bleed water has reached the steady state of distribution and concentration and is mixing away at a rate equal to its rate of supply, the filaments of a given concentration are somewhat too long, too thin and somewhat too narrow because of the deficient Reynolds number of the flow and dissimilar eddy diffusivity of the gravity controlled kinematic model. It is significant, and a result of this choice, that the principal effect of wind on the bleed water tracer pattern in the model is to drive it upwind on the bottom. Both in nature and in the model there is a surface layer driven downwind which is usually somewhat thinner and more vigorous than the upwind counter current on the bottom. In nature wave action and more intense eddy diffusion would tend to mix vertically the contents of the two layers, that is, the bleed water accumulated in the bottom counter current

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[6/] Question concerning the advisability of departing from Froude scaling arises only in connection with models of very shoal estuaries wherein wave action reaches to the bottom and wind circulation is important.

would be transported upward into the surface current and the uncontaminated surface water transported downward to dilute the concentrations present in the bottom counter current, and thus drive a more dilute solution of bleed water in both directions at once.

Wind velocity scales:- Wind stress on a model surface cannot be scaled from purely kinematic considerations because the factors concerned are primarily dynamic, and far from perfectly understood in nature. The transfer of energy by wind stress on the water surface involves considerations of at least the roughness of the interface, the temperature difference, temperature structures, eddy diffusivities, and densities of the two media, and probably the condition of the water surface skin. The surface roughness produced by simulated winds over small oceanographic models is usually too small due to the development of predominantly capillary waves rather than gravity waves. Capillary waves do not white-cap readily and they move faster as their lengths diminish while gravity waves move slower as their lengths diminish. Furthermore, to be in scale a modeled wave would have to have a scaled height y_r and a scaled length L_r in a distorted model. This latter requirement is often a physical impossibility. In view of all these difficulties it has been the practice to scale the model "wind" by scaling the translation effects it produces on the water surface. Oceanographic data indicate that where the fetch is greater than an equivalent of 5 to 10 thousand meters

and a steady state exists, an appreciable thickness of the surface water will be moving at a speed in the order of 2 to 3 per cent of the steady wind speed. In the Barataria Bay model the average steady wind speeds in each of the cardinal and intercardinal directions were computed from data supplied by the Grand Isle station of the U. S. Weather Bureau. The blowers were driven at the proper rate to produce a V_r scaled surface water motion equivalent to 2.5 per cent of the average wind speed wherever the fetch was great enough in each case. Every precaution was taken during the wind calibration and the model tests to have the model surface scrupulously clean so that the surface tension of the water skin maintained a uniform value and the rigidity of the skin was as low as possible. Before each test the surface was cleaned first by an ionic detergent and thereafter by a scummer. Tests were not begun until the detergent had had time to hydrolize and diffuse into the volumes of water below the surface. Since the action of the surface active agent is essentially monomolecular in thickness the resulting volume contamination was truly negligible.

The average wind velocities were calculated from statistics for the year 1946 prepared by the New Orleans Office, U. S. Weather Bureau, from observations made at Grand Isle, Louisiana, and are as follows:

	Wind direction symbol	Wind direction	Average wind speed (knots)	Water speed (knots)	Variac (volts)
Average spring-summer	WR	140°T	4.0	0.10	32.5
Average southeast wind	SE	135°T	9.0	0.22	41.0
Average autumn-winter	SR	085°T	7.8	0.20	39.0
Average east wind	E	090°T	10.0	0.25	40.0
Average northeast wind	NE	045°T	10.0	0.25	47.0
Average north wind	N	000°T	11.3	0.28	42.0
Average northwest wind	NW	315°T	9.5	0.24	41.0
Average west wind	W	270°T	8.9	0.22	39.0
Average southwest wind	SW	225°T	7.6	0.20	37.0
Average south wind	S	180°T	8.6	0.21	38.0

The direction of the average spring-summer wind being within 5° of southeast, the two directions were not distinguished and the higher average wind velocity was used as one test. The same distinction was omitted in the case of the average autumn-winter and the east wind which also differ in direction by 5°. Thus the actual wind velocities and directions used in the model tests were as follows:

	Wind direction symbol	Wind direction	Average wind speed (knots)	Water speed (knots)	Variac (volts)
"no wind" run to equilibrium	O	--	0.0	0.00	00.0
Spring-summer equilibrium	SR	140°T	9.0	0.22	41.0
Autumn-winter equilibrium	WR	085°T	10.0	0.25	40.0
Northeast wind equilibrium	NE	045°T	10.0	0.25	47.0
North wind equilibrium	N	000°T	11.3	0.28	42.0
Northwest wind equilibrium	NW	315°T	9.5	0.24	41.0
West wind equilibrium	W	260°T	8.9	0.22	39.0
Southwest wind equilibrium	SW	225°T	7.6	0.20	37.0
South wind equilibrium	S	180°T	8.6	0.21	38.0

The first three of these runs probably have greatest significance because they show first the action of the tides and rainfall in distributing the bleed water and then how the average conditions of the two major seasonal wind directions and forces influence this distribution. In nature the wind over Barataria Bay apparently does not often blow long enough from any of the non-prevailing directions to re-establish a corresponding equilibrium distribution of bleed water. Each of the wind runs in the model was carried through a little more than one semi-monthly change of the diurnal tide sequence. The equilibria represented in the films of the model undergo continuous cyclic modification as the contributions of the tidal, rainfall and wind circulation systems change in relative importance through a two-week period. The drawings of the results of these tests (Appendix III) show the accumulated greatest extension of bleed water pattern and do not represent the distribution at any one time. Distinction has been made between the continuous and intermittent distribution, some of which is tidal and some due to the changing direction and force of the winds.

V. THE TIDE MACHINE

The characteristic circulation in an estuary such as Barataria Bay is directly related to the daily and monthly sequence of tides. The design and calculations of the tide machine were taken from broader considerations than the tides observed in the estuary itself.

For proper representation of tidal currents in open coastline models the tide machine should be located offshore in the modeled portion of the sea. If possible it should be equidistant from all parts of the model coast line so that the cotidal lines of the wave will be initially parallel to the coast and thereafter altered by refraction as in nature. If it is known that the cotidal lines lie initially at some angle to the coast or are normal to it describing a progressive wave moving up or down the coast line, the tide machine and barriers should be located so as to simulate this approach. The more remote the position of the tide machine from the modeled embayment the more changed are the amplitudes of the tidal coefficients of the machine as they are amended to apply at the position offshore. Fortunately this amendment often allows simplification of the tide generator, for some of the important complicating constituents in the tidal records near the openings to estuaries are due to the behavior of a simple wave inside the estuary. Since the modeled estuary will provide these complicating effects of its own accord, they

should not be introduced twice. A good approximation of the final form of the offshore tide generator components can be obtained from a weighted average of the tidal coefficients at stations offshore or some distance away in both directions along the coast.

The complexity and rate of going of a tide generator varies with the character of the tidal trace both within and along the seaward margins of the prototype. The components of a tide machine are determined from the relative importance of each of the several tidal coefficients compared with their sum. Unimportant coefficients of the same tidal species can be collected and introduced as a single component driven at the weighted mean rate. Important species having speed numbers sufficiently close to this weighted mean can be added as well to simplify the mechanism. Separate components must be set apart if their amplitudes and speed numbers are such that they largely determine the characteristic sequence of tides. In middle latitudes near open sea coasts, the tides are predominantly semi-diurnal with more or less diurnal inequality and a semi-monthly sequence of ranges. If neither the diurnal inequality nor the semi-monthly range sequence is large, the tide can be closely approximated by a single drum of the proper displacement driven at the weighted mean rate of all the significant semi-diurnal species known for that station. If the diurnal inequality is too great to be neglected but the diurnal species are still unimportant, two semi-diurnal drums will suffice. If the diurnal species are important, and have a

strong semi-monthly sequence of amplitudes, or if the diurnal species are less important but not negligible, three drums will be required to produce an acceptable approximation of the tides. This is the case applicable to Barataria Bay.

The volume of water to be displaced in the model to effect the rise and fall of tides is the volume ratio $\left[(L_r)^2\ y_r\right]$ times the volume change (tidal prism) in the flooded areas of the prototype. To calculate the displacements of the tide machine drums it is possible to prorate the scaled volume of the tidal prism among the important harmonic constituents in proportion to the ratio of their amplitudes to the sum of all terms. This process automatically includes and distributes the minor contributions of the neglected components.

The basic data for the Barataria Bay tide machine were taken from

1. Tidal Harmonic Constants (Atlantic Ocean) TH-1 Jan. 1942
   U. S. Department of Commerce, Coast and Geodetic Survey
2. Tide Tables (Atlantic Ocean) Ser. 671, 1946.
   U. S. Department of Commerce, Coast and Geodetic Survey

The two stations Pensacola, Florida and Galveston, Texas distantly flanking Barataria Bay were chosen as a combination which would be free of conspicuous estuarine resonance and the average signatures of which would be indicative of the characteristic tidal oscillations on the proximal parts of the continental shelf of the Gulf of Mexico. The average of the two sets

of harmonic coefficients was taken as a first approximation of the open water tidal condition near the coast.

	K_1	O_1	P_1	Q_1	M_2	S_2	N_2	K_2 [7]
Pensacola (1934)	0.43	0.49	0.13	0.08	0.06	0.02	0.01	0.02
Galveston (1939)	0.38	0.35	0.10	0.08	0.31	0.10	0.08	0.01
2)	0.79	0.85	0.23	0.16	0.37	0.12	0.09	0.03
	0.39	0.43	0.12	0.08	0.19	0.06	0.05	0.01

Total range 1.24 feet

The small Q_1 and K_2 constituents were neglected as individuals and their contributions incorporated in the total displacement of the tide machine drums. Three drums were built and driven through a stroke of 2 inches at the following speeds:

	prototype	model	range	radius	displ.
K_1P_1 drum	24.00 hrs	60.0 sec.	0.51 "ft."	5.35 in.	181.0 in.^{3}
O_1 drum	25.82 hrs	64.5 sec.	0.43 "ft."	4.92 in.	152.2 in.^{3}
$M_2S_2N_2$ drum	12.21 hrs	30.5 sec.	0.30 "ft."	4.10 in.	106.0 in.^{3}
sum of all contributions			1.24 "feet"		440.2 in.^{3}

The final tests of this tide machine revealed errors of 3.2% in

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[7] See following page.

range and 15% in phase progress due to neglect of the longer period terms. The M_f and M_m constituents[7] were partly accounted for in rate adjustment of the O_1 and K_1P_1 drums.

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[7] K_1 = lunar declinational diurnal constituent, speed = 15°.041/m.s. hr.
O_1 = " " " " , speed = 13°.943/m.s. hr.
P_1 = solar " " " , speed = 14°.959/m.s. hr.
Q_1 = a lunar diurnal constituent , speed = 13°.399/m.s. hr.

M_2 = principal lunar semidiurnal constituent, speed = 28°.984/m.s. hr.
S_2 = principal solar semidiurnal constituent, speed = 30°.000/m.s. hr.
N_2 = larger lunar elliptic " " , speed = 28°.440/m.s. hr.
K_2 = luni-solar declinational semidiurnal " , speed = 30°.082/m.s. hr.

M_f = lunar fortnightly constituent , speed = 1°.098/m.s. hr.
M_m = lunar monthly harmonic constituent , speed = 0°.544/m.s. hr.

VI. KINEMATIC VERIFICATION OF THE MODEL

The effectiveness and reliability of an offshore tide machine in a model is best evaluated by comparison with the tide curves at the principal entrances to the estuary and against the accompanying velocities of flow and the times of slack with respect to high and low water in the prototype. These comparisons serve the additional purpose of verifying the kinematic similitude of the whole model.

The verification of the Barataria Bay model was considered consistent with the available data and acceptable when the sequences of times of slack water and maximum currents led or lagged the times of high and low water within one-half "hour" (1.25 sec.) of the times observed in the prototype by H. A. Marmer. Particle traverses were accepted when they agreed within $\frac{1}{4}$ "mile" of Marmer's predictions. Similarly the speeds and directions of the currents were accepted when they fell within less than one quarter "knot" of the speeds and 10° of the directions reported by Marmer in his reports on THE TIDE IN BARATARIA BAY and THE CURRENTS IN BARATARIA BAY. Further data on the details of the circulation around the Freeport Sulphur Company property were obtained by the writer or were supplied to him by V. H. Brogdon of the Freeport Sulphur Company. Particular attention was paid to the traverse of particles in Barataria Bay and to the asymmetry of duration of flood and ebb between St. Mary's point and the mouth of Bayou St.

Denis caused by the rain water drainage through the estuary. The latter is a distinguishing feature of the Barataria Bay circulation because it is indeed a river mouth of rather peculiar shape. Test A is concerned with a detailed study of rainfall drainage and its effect in tending to exclude the waters of both Lake Grande Ecaille and Bay Ronquille from Barataria Bay proper. In the eastern areas there is known to be an unusual division of the directions of ebb currents in the southern part of the Lake Washington system which causes the flood and ebb currents to diverge. Ebb currents flow north in part of Lake Washington and south in the region nearer Bay Chaland and reverse on the flood. The position of this division in the model was found to be in good agreement with field observations. Through the expedient of interposing the 20 by 20 mesh screens in the seaward passes the calculated rate of going of the tide machine was made acceptable. The calculated fresh water discharge through the Little Lake equivalent box led to a correct phase and duration of flood and ebb currents with respect to high and low water at Barataria Pass. Insofar as it is possible to estimate the reliability of a model with respect to field observations, the Barataria Bay model probably possessed a kinematic figure of merit of about 8 on a scale of 10. Since good quality field observations are generally rated at about this same figure of merit, and they alone reveal the behavior of the prototype, the estimated correspondence of the model to the true behavior of the prototype must be between 6

and 7 on a scale of 10. The higher figure is more likely in this case because the field observations were made by Marmer and his colleagues, whose sagacity is widely acknowledged.

VII. SPECIFICATIONS OF THE MODEL TESTS

The construction and verification of the Barataria Bay model discussed up to this point was of a routine nature and followed established precedents in most respects. The principal purpose of the model was to reconstruct the probable distribution of the maximum quantity of bleed water discharged at any time during the sulphur mining operations of the Freeport Sulphur Company. Toward this end apparatus was constructed which would discharge these maximum specified volumes as traceable material into the model at specified points under continuous discharge conditions. In each case the aim of the experiment was to determine the steady state distribution of the tracer under each of several wind conditions and at each of two dilution figures, namely 1 part in 200 and 1 part in 1000. The specifications for these discharge conditions were supplied by the Freeport Sulphur Company and are as follows:

Test A. Investigate the progress and distribution in the model of fresh water draining through the Barataria Bay estuary from the watershed to the north of Barataria Bay.

Test B. Investigate the distribution in the model of a tracer having theoretical kinematic similitude with specified bleed water and capable of showing dilution by the ambient water not in nominal excess of 1 part in 200 and 1 part in 1000 discharged at the points and at the rates given below:

at point VI, 1.4 million gallons per 24 hours, specific gravity 1.057[8] at 60°F,

at point VIII, 1.0 million gallons per 24 hours, specific gravity 1.024[8] at 60°F.

Test C. Duplicate Test B with the following additions: Investigate the distribution in the model of a tracer having theoretical kinematic similitude with specified bleed water and capable of showing dilution by the ambient water not in nominal excess of 1 part in 200 and 1 part in 1000 discharged at the point and rate given below:

at the head of the Freeport Sulphur Company dilution canal, 1.5 million gallons of bleed water per 24 hours, specific gravity 1.055[8] at 60°F,

add at the same point 40 million gallons of Lake Grande Ecaille water per 24 hours, specific gravity 1.012[8] at 60°F drawn in the model from the geometrically similar point at which this dilution water is drawn into the pumps in the prototype.

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[8] See discussion beginning at the bottom of page 39.

VIII. CHEMISTRY OF THE BLEED WATER TRACER

In order to meet the specified conditions of the model tests the bleed water was simulated by sulphuric acid of suitable strength and specific gravity and the ambient water by ordinary tap water to which was added a suitable quantity of sodium carbonate and a fraction of a gram of brom cresol green indicator per model volume of about 600 liters. This choice of solutions was made in order to reduce as much as possible any chemical reaction between the solutions and the gypsum (calcium sulphate) plaster of which the model was made and also to avoid alteration of pH of the ambient water through acidification by atmospheric carbon dioxide.

Sulphuric acid introduced to simulate the discharge of bleed water at the specified points and rates in the model necessarily produced a yellow color change in the brom cresol green indicator in solution with it. The color of brom cresol green in alkaline solution is a pleasant blue and the color change as the pH rises through the range 4.0 to 5.6 is at first green and then bright yellow. The change is abrupt from blue to green and more gradual from green to yellow. As the sulphuric acid flowed with the circulation of the model a certain amount of mixing took place which diluted the sulphuric acid, and at the same time reaction took place with the carbonate ions present in the admixed ambient water. The mixing processes were mainly due to molecular diffusion and microturbulent exchange across the interface between

the sulphuric acid solution and the ambient water. Thus there was a steep gradient of pH through this boundary and the color change of the indicator with pH was at first too abrupt for the individual stages of color to be discerned. As time passed and distance from the source increased the gradient between the acid and ambient alkali usually weakened sufficiently for the individual color changes to be observed. At length when the acid concentration was no longer sufficient to maintain a pH greater than 4.0 the acid became invisible, or neutralized. As pointed out earlier, mixing processes in the model were insufficient to represent the rate of mixing known from field evidence to exist in the prototype, and, since only mixing would permit the process of chemical neutralization to take place, the acid color of the bleed water tracer was generally maintained too long and too far from the source.

Generally speaking the concentration of a sulphuric acid and a sodium carbonate solution can be adjusted so that the intermediate color change from greenish yellow to green will take place when one volume of the acid is thoroughly mixed with any specified number of volumes of carbonate solution. One gram molecular weight of dilute sulphuric acid will be neutralized by one gram molecular weight of sodium carbonate in aqueous solution. Thus if a day's discharge of bleed water is represented by the discharge of a certain volume of liquid containing 0.01 gram molecular weight of sulphuric acid, the presence of this acid will be

detectable through the yellow or green color of the brom cresol green indicator present until the acid has had an opportunity to mix and react with a volume of ambient water containing 0.01 gram molecular weight of sodium carbonate. If the volume of 0.01 gram molecular weight of sulphuric acid solution is 1/1000 as great as the volume of ambient water containing 0.01 gram molecular weight of sodium carbonate solution, the boundary across which the acid ceases to be visible represents a dilution of the acid by a factor of 1000. Thus the color of the acid discharge was characteristic of pH lower than 4.0 and concentrations greater than 1 part in 1000, and invisible if its dilution exceeded this predetermined value. The same reasoning applies to the 1 part in 200 dilution contour. During operation of the model, samples of the solutions concerned in the bleed water tracer system were titrated repeatedly to end points in both the green and yellow ranges. These values represented the greatest and least measurable dilutions respectively of the acid component and served to define numerically the dilution contours represented by color changes in the model.

The chemical titrations of simulated bleed water against ambient water were referred to a standard sodium carbonate solution of approximately 0.2 normal strength. An intermediate standard sulphuric acid solution of approximately 0.01 normal strength was prepared in order to monitor the concentration of sodium carbonate in the ambient water. The simulated bleed water

solutions of sulphuric acid were made up in two liter quantities to a strength of approximately 0.5 normal for the 1 part in 1000 tests and approximately 0.1 normal for the 1 part in 200 tests. The exact normality of each solution was determined through comparison with the standard sodium carbonate solution. The standard sodium carbonate solution in turn was titrated against the intermediate standard acid solution. It was found that the acid prepared for the 1 part in 200 tests was 9.94 times as concentrated as the intermediate standard acid and that the acid prepared for the 1 part in 1000 tests was 50.2 times as concentrated as the intermediate standard acid. The entire mass of ambient water in the model was rendered suitably alkaline by addition of sodium carbonate. It was found that approximately 2.0 milliliters of the intermediate standard acid solution produced the blue-green to blue change of color in the brom cresol green indicator and that approximately 3.1 milliliters of intermediate standard acid produced the green-yellow color change when added to 50 milliliters of the sodium carbonate solution used as the ambient water. This ratio of concentrations was monitored by titrations throughout the model tests. During each test the dilution factor inevitably tended to shift. The average dilution factor was calculated for each run and the results of these calculations are tabulated in the log sheets and entered on the smooth plots of the results for each test. Two values are given; the value for the yellow-green change representing the highest measurable concentration of simulated bleed

water, and the value for the green-blue change representing the lowest measurable concentration of simulated bleed water. In each case it was the intention to make these values straddle the nominal dilutions specified for the tests. The dilutions were calculated as follows:

V_g = volume of Gulf water titrated (50 cc by volumetric pipette)
V_a = volume of intermediate standard acid used to neutralize V_g
V_b = volume of simulated bleed water equivalent to V_g

for 1:200 tests
$$\frac{V_g}{V_b} = 9.96 \times \frac{V_a}{V_b} \; ; \qquad (6)$$

for 1:1000 tests
$$\frac{V_g}{V_b} = 50.2 \times \frac{V_a}{V_b} \qquad (7)$$

IX. AUXILIARY PUMPING SYSTEMS

The scaled quantities of bleed water were pumped through 1/8-inch copper tubes embedded in the plaster monolith. These tubes were terminated at point VI on the north bank of Humble Canal, point VIII on the west bank of the dredge cut, at the head of the dilution canal and on the shore of Lake Grande Ecaille adjacent to the head of the dilution canal (see fig. 14). The first three tubes were attached to a positive displacement pump driven by an electric motor through suitable screw. The fourth tube was used to withdraw the dilution volumes from Lake Grande Ecaille for return at the head of the dilution canal together with the appropriate volumes of simulated bleed water. Thus the hydraulic activities of the Freeport Sulphur Company mining operations having significance in these tests were substantially reproduced in the model.

The kinematic scaling factor of discharge Q_r being $1/5.3 \times 10^7$ per mean solar day, the discharge per mean solar minute into the model is $Q_m = Q_p T_r$ or $1/7.68 \times 10^{10}$. One million gallons in the prototype is therefore represented in the model by a volume of 0.05 cubic centimeter of liquid or approximately one drop. Pumps that will deliver such small quantities of liquid per minute are difficult to build and to operate. In order to increase the volumes to be discharged by a single pumping unit, and to simplify the maintenance of predetermined differences of

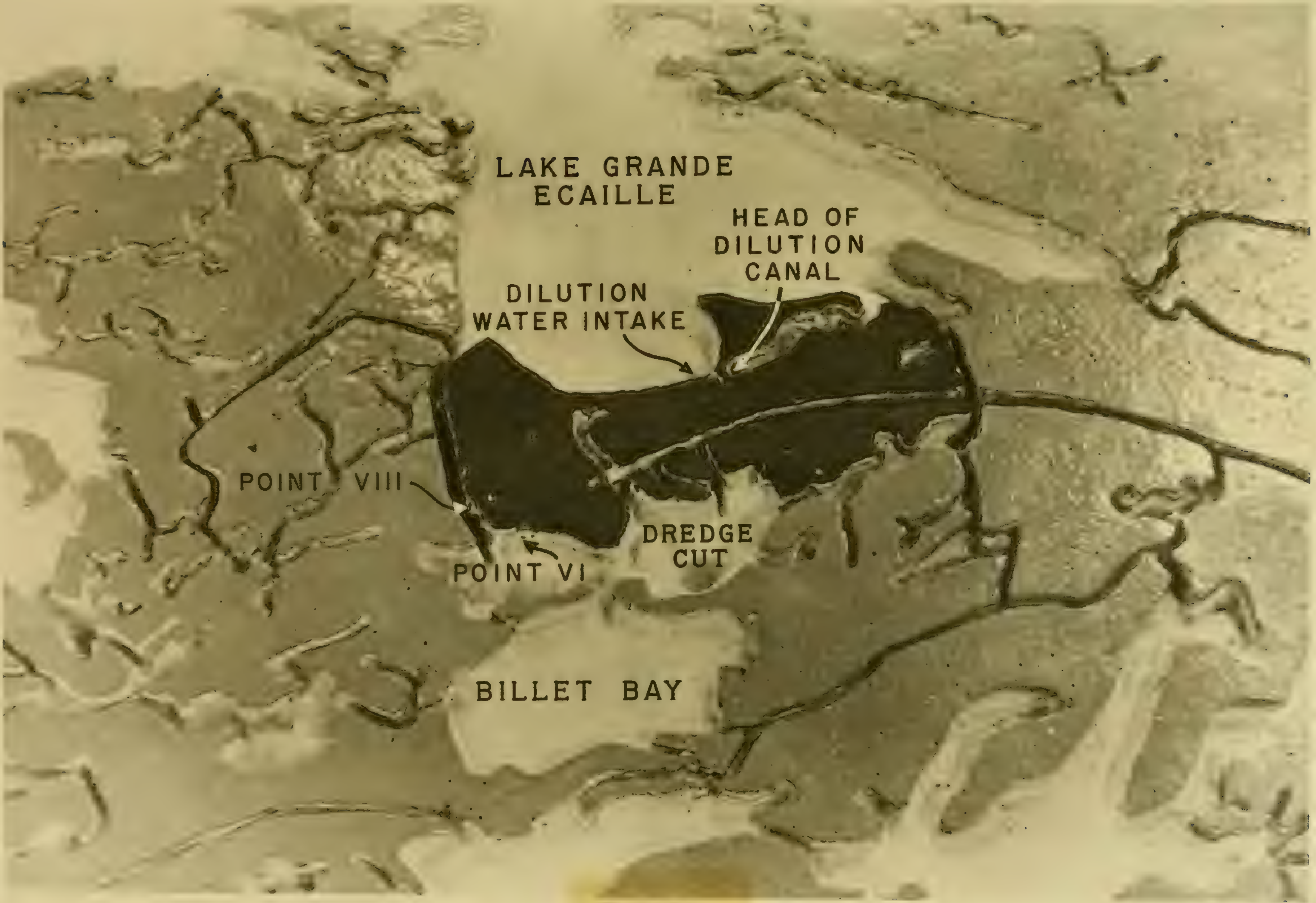
LAKE GRANDE ECAILLE
HEAD OF DILUTION CANAL
DILUTION WATER INTAKE
POINT VIII
DREDGE CUT
POINT VI
BILLET BAY

Figure 14.

specific gravity, which in this case were more significant than specific gravity ratios, permission was obtained to average the specified specific gravities of the simulated bleed waters and to maintain this average difference above that of the ambient water of specific gravity 1.000 at 60°F rather than 1.012. Since specific gravity is more easily measured than density and is numerically equivalent to density if comparisons are made at a convenient standard temperature, usually 60°F or 20°C, the resulting error in the equivalent density ratio was 1.2%. The average difference in specific gravity of the simulated bleed water and ambient water at 60°F was taken as 1.045 - 1.012 = 1.033 corresponding closely to that of a 5% NaCl solution at the same temperature. Thus the kinematic density difference 0.033 gm/cc, measured in terms of specific gravity under homogeneous temperature conditions equivalent to 60°F, was adjusted by adding the necessary quantities of Na_2SO_4 to the bleed water tracer.

A positive displacement pump had been designed and built to handle the sum of both the simulated bleed water volumes and the dilution volumes, but later it was thought better practice to actually withdraw the dilution volumes from the model since these volumes form a small but possibly significant part of the local circulation. Relieved of this relatively major burden the bleed water pump had to be run at very slow speeds, and during Test B it was found that accurate proportional delivery of the scaled volumes could not be detected and controlled quickly enough to

correct the "day-by-day" discharge rates but that the total discharge over a period of a "week" was acceptable. Since the points of discharge in Test B are so close together and united in a common portion of the detailed circulation no significant error in the equilibrium distribution of bleed water could occur as a result of small proportioning errors. In Test C, however, a small proportioning error would be highly significant in the equilibrium distribution of bleed water because the dilution canal is part of a circulation pattern that is distinct from the Humble Canal system. Test C was, therefore, not run until a reliable rotary proportioning device had been built and installed. The total discharge of the bleed water pump was monitored as before by timing the revolutions of the driving motor shaft and screw. The results obtained in all bleed water discharge tests are believed to be representative and consistent in spite of the difficulties enumerated.

Two other pumping systems had significance in the model tests (1) the dilution system which withdrew scaled volumes of water from Lake Grande Ecaille and discharged them as a mixture with properly scaled volumes of bleed water added, and (2) the rainfall pumping system. The bleed water dilution system consisted of a small gear pump driven by a separate electric motor and monitored by counting the number of drops discharged per minute as they fell from a calibrated dropper tip. Since the scaled volumes involved a drop every few seconds it was possible to observe the rate of

discharge quite readily and maintain acceptable accuracy. Similarly the rain water circulation system involved the discharge of 165 cubic centimeters per minute, a volume equivalent to Marmer's estimate of the average fresh water drainage (450×10^6 ft.^{3}/day) into Barataria Bay. This volume was pumped from the Gulf portion and was piped around the outside of the model to the Little Lake equivalent box where it discharged as a small steady stream. This flow was adjusted by means of a needle valve at the pump. The same pump also circulated a continuous stream in the Gulf of Mexico portion of the model through a venturi tube which entrained the Gulf water and produced the characteristic westward trend of the circulation of Gulf past the mouths of the passes into the Barataria Bay estuary. The venturi system was adjusted to produce a steady westward current of 0.25 "knot" along the coast line.

X. THE RELIABILITY OF THE MODEL TESTS

The final figure of merit for all the observations represented in the model tests can be estimated only very roughly. The model itself is rated at 7 on a scale of 10. The equilibrium distribution of bleed water in the model is estimated at the same figure. Hence the reliability of the bleed water tracer tests must be about 5 on a scale of 10. This figure of merit should be interpreted to mean that the contours of bleed water distribution may be overextended with respect to the actual occurrence in the prototype by a factor of 2 or they may be underextended by a factor of 1/2. The kinematic density scale chosen in connection with simulated bleed water discharge caused the bleed water to sink unnaturally and inhibit the mixing processes that would otherwise dilute the discharge. With the condition of insufficient mixing applying so heavily to the first possibility and to the estimate of the figure of merit itself, underextension of the dilution contours of bleed water distribution is improbable.

XI. "FIRST ARRIVAL" TESTS

In addition to the tests for the equilibrium distribution of bleed water and penetration of fresh water discharge some separate tests were run and photographed to determine the minimum time required for a parcel of water composed of an hour's discharge from point VI in Humble Canal to travel to the head of Bay Ronquille. It was found that the volume of colored ink tracer released at point VI had to be deposited at a very critical moment near the beginning of a tropical ebb tide in order to reach the head of Bay Ronquille before the following flood carried it back toward its starting point. The minimum time required for a parcel to actually reach the head of Bay was approximately seven or eight hours.

Experiments in the field show that the travel time on the tropical flood tide from point VI in Humble Canal to Fisherman's cut on the east side of the Freeport Sulphur Company dredge cut is about five hours. The model confirms this result provided the tracer has neutral density. If the tracer is of kinematically (1/1) scaled density the discharge through Fisherman's cut is delayed until the dredge cut basin is filled and a stratified layer established which is almost level with the threshold of Billet Bay. Following this the travel time is the same for solutions of both neutral and kinematic density.

Appendix I - Schedule of procedure in model tests.

Preliminary readiness check

1. check titre of ambient water and sea level, clean water surface
2. check specific gravities of ambient water and simulated bleed water for difference of 0.033
3. check rate of fresh water discharge at 165 cc/min.
4. check filling of bleed water pumps with proper acid solution
5. check rate of discharge of bleed water pump
6. blow out bleed water discharge lines and flush with ambient water
7. fill bleed water discharge lines with proper acid solution to point of incipient discharge
8. check rate of going of tide machine
9. check tide recorder for ink and paper supply
10. check wind sock
11. check run code number
12. replace all photofloods and test lighting system, measure illumination
13. check power to wind machines, and alignments
14. check film supplies, cameras and exposures
15. check velocity of flow through Barataria Pass, Bayou St. Denis

Operating duties

Chemist

1. keep running check and log of titre of ambient water
2. operate wind machines on signal
3. place and remove wind sock on signal
4. change code numbers on signal
5. replace photoflood lamps as necessary

Mechanist

1. keep continuous watch on bleed water discharge rate, dilution pump rate, tide machine rate and fresh water discharge
2. start and stop and label tide recorder on signal
3. start and set elapsed-time clock on signal
4. replace photoflood lamps as necessary

Photographer

1. keep continuous watch on framing, exposure, focus and film supply of all cameras, change film as required
2. keep watch on the over-all behavior of the model
3. general instructions for operating 16 mm time-lapse and 35 mm Graflex cameras
   a. operate 16 mm time-lapse Bolex with 15 mm Eastman Cine f-2.7 objective and Type A Kodachrome in 100 foot rolls at the rate of 1 frame per second
   b. operate 35 mm Graflex Photorecord camera with 44 mm Wollensak f-3.2 objective at air pressure of 22 lbs using 100 foot rolls Type A Kodachrome at the rate of 1 frame every 7.5 seconds. Synchronize with model clock
   c. operate 35 mm Leica with 127 mm Wollensak objective f-4.5 at optional intervals during runs to equilibrium and at intervals of approximately one week during wind tests. Include the vicinity immediately adjacent to Freeport Sulphur Company area in field of view. Try to record significant changes or developments of the bleed water patterns.
4. make serial photographic record of model tests as follows:
   a. run to equilibrium without wind - run both 16 and 35 mm cameras
   b. run to summer wind equilibrium - run both 16 and 35 mm cameras
   c. return to no-wind equilibrium - no photographs
   d. run to winter wind equilibrium - run both 16 and 35 mm cameras
   e. return to no-wind equilibrium - no photographs
   f. cardinal and intercardinal winds - start 16 and 35 mm cameras when equilibrium is attained, continue photographing until one-half monthly progression of tides has passed.
5. keep log of photographs and model behavior

Completion duties

1. secure all electrical machinery and lighting equipment
2. flush model free of distributed acid
3. dry off land areas with sponges
4. secure work lights

APPENDIX II

The pages that follow contain a chronological transcript of the photographic and chemical logs written during the model tests. In explanation of the various symbols used to designate the tests:

1. The tests were designated A, B, and C; which designations connote briefly

   Test A:- fresh water drainage through the estuary
   Test B:- bleed water discharge from points VI and VIII
   Test C:- bleed water discharge from points VI, VIII
   and from the dilution canal

2. Each of the B and C tests was run so that dilution of bleed water by ambient water would be shown at nominally 1 part in 200 and 1 part in 1000. These dilution factors are represented by the roman numerals CC and M respectively.

3. In addition, a separate combination of each of the B and C tests and each dilution factor was run under winds from the cardinal and intercardinal directions N, E, S. W, and NE, SE, SW, NW respectively with the qualification that E was replaced by the average summer wind and labeled SR. Test A was run only under no-wind conditions and this and the phases of the other tests run without wind are labeled O in the wind column.

Thus a test designated BNEM, for example, means; test B discharge conditions, NE wind conditions, M or 1 part in 1000 dilution conditions. In general one test was run in one day. The time of day for each occurrence is given in local standard time and the elapsed time from the beginning of the model test is reckoned in model "days" of one mean solar minute duration.

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

3 October 1949 PRELIMINARY TESTS OF EQUIPMENT

TRIAL OF FRESH WATER (RAINFALL) DISCHARGE EXPERIMENT

Model filled to tide datum with clear fresh ($\rho = 1.000$) tap water. Brom Cresol Green solution added at Little Lake equivalent box to trace fresh water drainage pattern.
Tide machine set to run at 31.5 sec. semi-diurnal cycle.
Fresh water discharge rate adjusted to 168 cc/min.
Density difference zero, in this case.
Cameras used for all model runs; (at a working distance 16 feet over center of model except 3 at 14 ft.).

1. Graflex Photorecord pneumatic camera, 35 mm double frame, Bolsey f-3.2 Wollensak Anastigmat, 44 mm f.l., Bolsey shutter, automatic exposure interval 7.5 sec., Exp. 1/10 sec., f-9.5, 800 exp./roll
2. Paillard Bolex time-lapse motion-picture camera, 16 mm single frame, Eastman Kodak f-2.7 Cine Anastigmat, 15 mm f.l., automatic exposure interval 1 second, 1/30 sec., f-6.3, 95 ft. rolls, 3800 exp./roll
3. Leica C-III, 35 mm double frame hand camera, Wollensak f-4.5 Velostigmat f.l. 127 mm, manual exposure control, exp. 1/8 sec., f-11, working distance 14 feet over F.S. Co. operating area

Film Kodachrome Type A in 100 foot 35 mm spools for Graflex (1)
Kodachrome Type A in 95 foot 16 mm spools for Bolex (2) cut down from 200 foot spools
Kodachrome Type A in 20 and 36 exposure cassettes for Leica (3)

Illumination 12 No. 2 Photoflood lamps in reflectors operating at 115 volts, A.C.

3 Oct.'49	
1405	Brom Cresol Green added to equivalent box, cameras started, no wind, clock 0^{mo} 0^{da} 0^{hr}
1419	Brom Cresol Green added to equivalent box
1420	Cameras jammed
1427	Cameras cleared
1428	Cameras jammed, trouble in gravity trigger, secured run. Drained model, refilled with fresh tap water to msl datum, camera triggers repaired, test repeated
1516	Cameras restarted
1518	Brom Cresol Green added to equivalent box
1550	" " " " " " "
1600	" " " " " " "
1619	Reloaded 16 mm camera
1626	16 mm take-up spool jammed for approximately 30 sec. before being cleared
1643	35 mm magazine emptied
1658	Brom Cresol Green added to equivalent box
1736	Test secured. At 105 "days" fresh water discharge reached Lake Washington

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

4 October 1949 ACID AND WATER DENSITY* ADJUSTMENTS

Two 4-liter Ehrlenmeyer flasks prepared with 3-4 liters of Dil. H_2SO_4 as follows:
1. Labeled "200:1" containing approximately 0.1 N H_2SO_4 + Brom Cresol Green sp.gr. = 1.006 at 60°F
2. Labeled "1000:1" containing approximately 0.5N H_2SO_4 + Brom Cresol Green sp.gr. = 1.033 at 60°F

average sp.gr. of prototype Point VI 1.057
bleed water Point VIII 1.024
at 60°F raw 1.055
3)3.136
1.045

average sp.gr. of ambient water at 60°F 1.012
Difference 0.033 ≡ equivalent $\Delta\rho$ = 0.033 gm/cc.

$1 + \Delta\rho \equiv$ 5% NaCl solution ρ = 1.033 gm/cc.
Sp.gr. of "1000:1" acid solution at 60°F = 1.033 without adjustment but "200:1" sp.gr. was 1.006. Increased specific gravity of "200:1" solution by adding Na_2SO_4 crystals until hydrometer read sp.gr. = 1.033 at 60°F. Equivalent $\Delta\rho$ for both solutions 0.033 gm/cc. greater than ambient water of density 1.000 gm/cc.

Additional solutions made up for titration control during tests.
1. Intermediate standard H_2SO_4 solution approximately 0.01 N, = "200:1" solution cut nominally 10:1.
2. Reference Na_2CO_3 solution approx. 0.2 N for comparison of acid solutions.

Titration of "200:1" solution and 1/10 cut "200:1" solution showed actual cut to be 9.94:1
Titration of "1000:1" solution and 1/50 cut "1000:1" solution showed actual cut to be 50.2:1

Thus dilution factor nominally "200:1" is

$$9.94 \times \frac{\text{(50 cc volume sample of ambient Gulf water)}}{\text{(volume intermediate standard acid to neutralize Gulf sample)}} \text{ in fact,}$$

and dilution factor nominally "1000:1" is

$$50.2 \times \frac{\text{(50 cc volume sample of ambient Gulf water)}}{\text{(volume intermediate standard acid to neutralize Gulf sample)}} \text{ in fact.}$$

*Density is ordinarily considered in model theory but in practice specific gravity is the quantity most conveniently measured. Therefore, density in each case was measured in terms of specific gravity at 60°F. The results are numerically equivalent to density but differ dimensionally as indicated.

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

5 October 1949 TEST B _ M

Isolated discharge from points VI and VIII at F.S. Co. mining area for 1946.

BOM		fresh water discharge set at 168 cc/min. ≅ 450 x 10^6 ft.^{3}/day bleed water discharge equivalent to 2.4 x 10^6 gal./day	Sample time	ml.stand.acid initial	ml.stand.acid final	Δ	end point
1245	0 da	bleed water discharge started					
1245	0 da	start 35 mm at 0 exp. 1/10 sec. f-9.5					
1245	0 da	start 16 mm at 0 ft. f-6.3					
1300		Secured. Shutter main spring fouled. Stopped run at 150 exp. Flushed model					
BOM							
1423	0 da	bleed water discharge started	1426	12.80	16.00	3.20	yellow
1423	0 da	start 35 mm at 150 exp. 1/10 sec. f-9.0					
1423	0 da	start 16 mm at 25 ft. f-6.3					
1439	14 da	exp. 4. Leica 127 mm 1/8 sec. f-11					
1453	28 da	exp. 5. Leica 127 mm 1/8 sec. f-11	1441	17.75	19.63	1.88	bl.gr.
1505	Note:	bleed water "stores up" during diurnal tides and "expands" on tropical					
1507	42 da	exp. 6. Leica 127 mm 1/8 sec. f-11	1511	19.63	21.63	2.00	bl.gr.
1516	50 da	changed 16 mm spools					
1521	56 da	exp. 7. Leica 1/8 sec. f-11					
1525	60 da	exp. 8. Leica 1/8 sec. f-11					
1526	61 da	16 mm camera missing; adjusted trigger stroke					
1546	81 da	exp. 9. Leica 1/8 sec. f-11					
1548	83 da	changed 35 mm magazines					
1600	95 da	exp. 10. Leica 1/8 sec. f-11					
1615	110 da	35 mm magazine balky; moved film to old magazine	1611	21.63	23.60	1.97	bl.gr.

BOM			Sample time	ml.stand.acid initial	final	Δ	end point
1625	120 da	exp. 11. Leica 1/8 sec. f-11					
1635	120 da	16 mm camera film changed					
1647	142 da	exp. 12. Leica 1/8 sec. f-11					
1659	155 da	exp. 13. Leica 1/8 sec. f-11					
1725	180 da	exp. 14. Leica 1/8 sec. f-11	1711	23.60	25.50	1.90	bl.gr.
1725	180 da	secured; 35 mm 750 exp.	1711	23.60	26.51	2.91	yellow
1725	180 da	" 16 mm 95 ft.					
		Note: Last seven days to be ignored - 50 drops of bleed water (50 x 10^6 gal. approximately) accidentally discharged 10 "days" before SR wind experiment began. Bay Long heavily colored during 1st week of SR run but returned to normal during second week.					

yellow average $\frac{50.2 \times 50}{3.06}$ =

1 part/ 822

bl.gr. average $\frac{50.2 \times 50}{1.94}$ =

1 part/1294

median = 1 part/1058

BSRM		
1729	0 da	SR wind started
1739	10 da	exp. 15. Leica 1/8 f-11
1746	18 da	started 16 mm camera 0 ft.
1754	26 da	" 35 mm camera
1758	30 da	exp. 16. Leica 1/8 f-11
1808	40 da	" 17. " " "
1811	42 da	" 18. " " "
1811	42 da	stopped 35 mm camera at 150 exp.
1811	42 da	stopped 16 mm camera at 39 ft.
1815		fresh water discharge checked at 170 cc/min.

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

6 October 1949 TEST B _ M

Isolated discharge from points VI and VIII at F.S. Co. mining area for 1946.

			Sample time	ml.stand.acid initial	final	△	end point
BWRM		fresh water discharge set at 163 cc/min. ≅ 450 x 10^6 ft.^{3}/day ran model 6 "months" to no wind equilibrium. About 50% excess bleed water discharged during first two "months" corrected to equivalent of 2.4 x 10^6 gal./day discharge rate 4 "months" before beginning BWRM					
1432		WR wind started					
1432	0 da	start 16 mm camera f-6.3 39 ft. initial footage					
1436	3 da	exp. 19. Leica 1/8 f-11	1437	3.10	5.10	2.00	bl.gr.
1447	12 da	start 35 mm camera 1/10					
		f-9.5, 150 exp. initial	1437	3.10	6.60	3.50	yellow
1449	14 da	exp. 20. Leica 1/8 f-11					
1457	21 da	" 21. " " "	1452	6.80	8.80	2.00	bl.gr.
1510	35 da	" 22-23 " " "	1452	6.80	10.10	3.30	yellow
		two tide stages					
1513	38 da	Secured 35 mm, 350 exp.					
1513	38 da	" 16 mm, 95 ft.					
		bleed water pump under control but leaking discharge measured by counting drops; discharge may be 20% too great					
BNEM							
1519	0 da	NE wind started					
1525	6 da	started 35 mm, 350 exp. initial					
1525	6 da	started 16 mm, 0 ft., f-6.3	1522	10.10	12.10	2.00	bl.gr.
1543	24 da	exp. 24 Leica 1/8 f-11	1522	10.10	13.20	3.10	yellow
1549	30 da	" 25 " " "					
1554	35 da	" 26 " " "					
1558	38 da	Secured. 35 mm, 510 exp.					
1558	38 da	" 16 mm, 31 ft.					
BNM							
1559	0 da	N wind started					
1612	13 da	start 35 mm camera 1/10 f-9.5, 520 exp.					
1612	13 da	start 16 mm camera f-6.3 33 ft.					
1613	14 da	exp. 27 Leica 1/8 f-11					
1619	21 da	" 28 " " "	1615	13.30	15.30	2.00	bl.gr.

6 October 1950 TEST B _ M (continued)

			Sample time	ml.stand.acid initial	ml.stand.acid final	△	end point
BNM							
1627	28 da	exp. 29 Leica 1/8 f-11	1615	13.30	16.40	3.10	yellow
1630	30 da	secured; 35 mm 660 exp.					
1630	30 da	" 16 mm 58 ft.					
BNWM							
1631	0 da	NW wind started					
1644	13 da	start 35 mm 1/10 f-9.5 660 exp.					
1644	13 da	start 16 mm f-6.3 58 ft.					
1645	14 da	exp. 30 Leica 1/8 f-11	1647	16.55	18.55	2.00	bl.gr.
1656	25 da	" 31 " " "	1647	16.55	19.65	3.10	yellow
1659	28 da	" 32 " " "					
1703	31 da	secured; 35 mm 800 exp.					
1703	31 da	" 16 mm 87 ft.					
BWM							
1704	0 da	W wind started					
1717	13 da	start 35 mm 0 exp. 1/10 f-9.5					
1717	13 da	start 16 mm 0 ft. f-6.3					
1718	14 da	exp. 33 Leica 1/8 f-11	1720	19.80	21.80	2.00	bl.gr.
1725	21 da	" 34 " " "	1720	19.80	22.90	3.10	yellow
1732	28 da	" 35 " " "					
1735	31 da	secured; 35 mm 160 exp.					
1735	31 da	" 16 mm 30 ft.					
BSWM							
1737	0 da	SW wind started					
1750	13 da	start 35 mm 160 exp. 1/10 f-9.5					
1750	13 da	start 16 mm 31 ft. f-6.3					
1751	14 da	exp. 36 Leica 1/8 f-11	1755	22.90?	25.30	2.40?	bl.gr.
1758	21 da	" 37 " " "	1755	22.90?	26.10	3.20?	yellow
1805	28 da	" 38 " " "	1758	26.10	28.10	2.00	bl.gr.
1808	31 da	secured; 35 mm 310 exp.	1758	26.10	29.10	3.00	yellow
1808	31 da	" 16 mm 58 ft.					
BSM							
1809	0 da	S wind started					
1823	14 da	start 35 mm 310 exp. 1/10 f-9.5					
1823	14 da	start 16 mm 58 ft. f-6.3					
1823	14 da	exp. 1 Leica 1/8 f-11	1825	29.30	31.30	2.00	bl.gr.
1830	21 da	" 2 " " "	1825	29.30	32.40	3.10	yellow
1838	28 da	" 3 " " "					
1841	31 da	secured 35 mm 450 exp.					
1841	31 da	" 16 mm 85 ft.					

yellow average (50.2 x 50)/3.16 = 1 part/ 793

bl.gr. average (50.2 x 50)/2.00 = 1 part/1253

median = 1 part/1023

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

7 October TEST B _ CC

Isolated discharge from points VI and VIII at F.S. Co. mining area for 1946.

BOCC			Sample time	ml.stand.acid initial	final	△	end point
		test equilibrium under no wind; fresh water discharge set 166 cc/min. ≡ 450 x 10^6 ft.^{3}/day; bleed water discharge measured by screw revolutions since system no longer leaks; drive 7^m 18^s/rev. ≡ 2.4 x 10^6 gal./day. Proration error of discharge to Points VI & VIII may be ± 40% at times.					
0950	-1.5da	start 16 mm 0 ft..f-6.3	0945	00.00	02.00	2.00	bl.gr.
0952	0 da	bleed water discharged started	0945	00.00	03.10	3.10	yellow
1006	14 da	exp. 4 Leica 1/8 sec. f-11					
1027	35 da	exp. 5 Leica 1/8 sec. f-11					
1039	42 da	exp. 6 Leica 1/8 sec. f-11					
1043	51 da	exp. 7 Leica 1/8 sec. f-11	1040	03.10	05.10	2.00	bl.gr.
1048	56 da	exp. 8 Leica 1/8 sec. f-11	1040	03.10	06.30	3.20	yellow
1052	60 da	start 35 mm 1/10 f-9.5 460 exp. initial					
1057	65 da	reloaded 16 mm camera f-6.3,0 ft.					
1059	67 da	exp. 9 Leica 1/8 sec. f-11					
1108	76 da	exp. 10 Leica 1/8 sec. f-11					
1115	83 da	exp. 11 Leica 1/8 sec. f-11					
1122	90 da	exp. 12 Leica 1/8 sec. f-11					
1132	100 da	exp. 13 Leica 1/8 sec. f-11	1135	06.70	08.70	2.00	bl.gr.
1137	105 da	secured 35 mm at 800 exp.	1135	06.70	09.80	3.10	yellow
1137	105 da	" 16 mm at 55 ft.					
BSRCC							
1138	0 da	start SR wind					
1138	0 da	start 16 mm 55 ft. initial f-6.3					
1151	13 da	start 35 mm 0 exp. 1/10 f-9.5					

			Sample time	ml.stand.acid		△	end point
BSRCC				initial	final		
1152	14 da	exp. 14 Leica 1/8 sec. f-11	1155	09.85	12.10	2.35	bl.gr.
1159	21 da	exp. 15 Leica 1/8 sec. f-11	1155	09.85	13.20	3.35	yellow
1206	28 da	exp. 16 Leica 1/8 sec. f-11	Brom Cresol Green + Na_2CO_3 added at venturi				
1207?	29 da?	16 mm film ran out, no time to reload before end of run	1200	13.20	15.40	2.20	bl.gr.
			1200	13.20	16.40	3.20	yellow
1208	30 da	secured 35 mm at 145 exp.	Brom Cresol Green + Na_2CO_3 added at venturi				
			1205	16.40	18.60	2.20	bl.gr.
			1205	16.40	19.80	3.40	yellow
			Brom Cresol Green + Na_2CO_3 added at venturi				
BWRCC							
		returned to no wind equilibrium 1208 to 1312					
1312	-1 da	start 16 mm f-6.3 0 ft.					
1313	0 da	start WR wind					
1313	0 da	exp. 17 Leica 1/8 sec. f-11					
1320	7 da	exp. 18 Leica 1/8 sec. f-11	1315	19.80	22.00	2.20	bl.gr.
1326	13 da	start 35 mm 1/10 f-9.5 145 exp. initial	1315	19.80	23.10	3.30	yellow
1327	14 da	exp. 19 Leica 1/8 sec. f-11					
1334	21 da	exp. 20 Leica 1/8 sec. f-11					
1341	28 da	exp. 21 Leica 1/8 sec. f-11					
1344	31 da	secured 35 mm at 295 exp.					
1344	31 da	" 16 mm at 49 ft.					
BNECC							
1345	0 da	start NE wind					
1358	13 da	start 35 mm 295 exp. initial 1/10 f-9.5					
1358	13 da	start 16 mm 49 ft. initial f-6.3					
1359	14 da	exp. 22 Leica 1/8 sec. f-11					
1406	21 da	exp. 23 Leica 1/8 sec. f-11	1408	14.45	16.65	2.20	bl.gr.
			1408	14.45	17.75	3.30	yellow
1413	28 da	exp. 24 Leica 1/8 sec. f-11					
1416	31 da	secured 35 mm at 440 exp.					
1416	31 da	" 16 mm at 75 ft.					

BNCC			Sample time	ml.stand.acid		△	end point
				initial	final		
1417	0 da	start N wind (wind indicator unstable)					
1430	13 da	start 35 mm at 440 exp. 1/10 f-9.5					
1430	13 da	start 16 mm 0 ft. f-6.3					
			1432	17.80	19.90	2.10	bl.gr.
			1432	17.80	21.10	3.30	yellow
1436	19 da	exp. 25 Leica 1/8 sec. f-11					
1438	21 da	exp. 26 Leica 1/8 sec. f-11					
1445	28 da	exp. 27 Leica 1/8 sec. f-11					
1448	31 da	secured 35 mm at 590 exp.					
1448	31 da	" 16 mm at 26 ft.					
		stabilized wind sock by oil damping					
BNWCC							
1449	0 da	start NW wind					
1503	14 da	start 35 mm at 590 exp. 1/10 f-9.5					
1503	14 da	start 16 mm at 26 ft. f-6.3					
1503	14 da	exp. 28 Leica 1/8 sec. f-11	1505	21.20	23.40	2.20	bl.gr.
1510	21 da	exp. 29 Leica 1/8 sec. f-11	1505	21.20	24.40	3.20	yellow
1517	28 da	exp. 30 Leica 1/8 sec. f-11					
1520	31 da	secured 35 mm at 730 exp.					
1520	31 da	" 16 mm at 54 ft.					
BWCC							
1521	0 da	start W wind					
1534	13 da	start 35 mm 0 exp. 1/10 f-9.5					
1534	13 da	start 16 mm 55 ft. f-6.3					
1535	14 da	exp. 31 Leica 1/8 f-11	1535	24.40	26.60	2.20	bl.gr.
			1535	24.40	28.00	3.60	yellow
1542	21 da	exp. 32 Leica 1/8 f-11					
1549	28 da	" 33 " " "					
1550	clock	" 34 " " "					
1553	32 da	secured 35 mm at 150 exp.					
1553	32 da	" 16 mm at 83 ft.					
BSWCC							
1553	0 da	start SW wind					
1607	14 da	start 35 mm at 150 exp. 1/10 f-9.5					
1607	14 da	start 16 mm at 0 ft. f-6.3					

7 October 1949 TEST B _ CC (continued)

BSWCC			Sample time	ml.stand.acid initial	ml.stand.acid final	Δ	end point
1607	14 da	exp. 2 Leica 1/8 sec. f-11	1610 1610	00.20 00.20	02.30 03.70	2.10 3.50	bl.gr. yellow
1615	21 da	exp. 3 Leica 1/8 sec. f-11					
1622	28 da	exp. 4 Leica 1/8 sec. f-11					
1625	32 da	secured 35 mm at 300 exp.					
1625	32 da	" 16 mm at 28 ft.					
BSCC							
1626	0 da	start S wind					
1638	12 da	start 35 mm at 300 exp. 1/10 f-9.5					
1638	12 da	start 16 mm at 28 ft. f-6.3					
1640	14 da	exp. 5 Leica 1/8 sec. f-11	1640 1640	03.80 03.80	05.80 06.95	2.00 3.15	bl.gr. yellow
1647	21 da	exp. 6 Leica 1/8 sec. f-11					
1654	28 da	exp. 7 Leica 1/8 sec. f-11					
1657	32 da	secured 35 mm at 450 exp.					
1657	32 da	" 16 mm at 56 ft.					
		fresh water discharge check 108 cc/min value 30% low tends to retain bleed water in estuary for a longer than normal time					

yellow average $\frac{9.94 \times 50}{3.29} =$

1 part / 151

bl.gr. average $\frac{9.94 \times 50}{2.14} =$

1 part / 234

median = 1 part/ 193

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

10 October 1949 TEST C _ CC

Bleed water discharge from all points (including dilution canal) characteristic of 1946 operations.

COCC			Sample time	ml.stand.acid		Δ	end point
				initial	final		
		test equilibrium under no wind; fresh water discharge rate set 164 cc/min. ≅ 450 x 10^6 ft.^{3}/day; total bleed water discharge rate set 4^m 44^s/rev. ≅ 3.7 x 10^6 gal./day; dilution water discharge rate 40 drops/min. ≅ 40 x 10^6 gal./day					
1409	-2 da	start 35 mm at 460 exp. 1/10 f-10.0					
1409	-2 da	start 16 mm at 57 ft. f-6.3					
1411	0 da	bleed water discharge started	1414	09.65	11.55	1.90	bl.gr.
			1414	09.65	12.80	3.15	yellow
1418	7 da	exp. 8 Leica 1/8 sec. f-11					
1424	13 da	35 and 16 mm camera frame leveled					
1425	14 da	exp. 9 Leica 1/8 sec. f-11					
1433	21 da	exp. 10 Leica 1/8 sec. f-11					
1437	24 da	reloaded 16 mm camera					
1441	30 da	exp. 11 Leica 1/8 sec. f-11	1452	00.00	02.10	2.10	bl.gr.
1458	47 da	reloaded 35 mm magazine	1452	00.00	03.50	3.50	yellow
1500	49 da	exp. 12 Leica 1/8 sec. f-11					
1512	60 da	exp. 13 Leica 1/8 sec. f-11					
1529	75 da	exp. 14 Leica 1/8 sec. f-11					
1542	90 da	exp. 15 Leica 1/8 sec. f-11					
1547	95 da	reloaded 16 mm camera					
			1550	03.55	05.75	2.20	bl.gr.
1611	120 da	exp. 16 Leica 1/8 sec.	1550	03.55	07.30	3.75	yellow
		f-11 equilib. max.ebb	1554	07.30	09.50	2.20	bl.gr.
1617	126 da	exp. 17	1554	07.30	10.80	3.50	yellow
		Leica equilib. max.flood 1/8 sec. f-11					
1617	126 da	exp. 18, Leica 1/8 sec. f-11					

10 October 1949 TEST C _ CC (continued)

COCC

1627	136 da	exp. 19 Leica 1/8 sec. f-11
1642	150 da	exp. 20 Leica 1/8 sec. f-11
1642	150 da	secured 35 mm at 850 exp.
1642	150 da	" 16 mm at 95 ft.
		35 mm camera shutter operates uncertainly; will repeat this run after repairs

Sample time	ml.stand.acid initial	final	△	end point

yellow average $\frac{9.96 \times 50}{3.46} =$
1 part / 145

bl.gr. average $\frac{9.96 \times 50}{2.10} =$
1 part / 233

median = 1 part / 189

11 October 1949

COCC

		repeat run conditions as on 10 October 1949
1312	0 da	ran experiment 330 days but
1645	11 mo	took no photographs because model behaved strangely (trouble later found to be draft from open loft windows)

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

12 October 1949 TEST C _ CC

Bleed water discharge from all points (including dilution canal) characteristic of 1946 operations.

COCC			Sample time	ml.stand.acid		△	end point
				initial	final		
		fresh water discharge 166 cc/min. ≅ 450 x 10^6 ft.^{3}/day; bleed water discharge rate 4^m 44^s/rev. ≅ 3.7 x 10^6 gal./day; rotary bleed water distributor installed; dilution water discharge rate 40 drops/min. ≅ 40 x 10^6 gal./day					
0902	0 da	bleed water discharge started	0935	12.40	14.70	2.30	bl.gr.
			0935	12.40	15.90	3.50	yellow
			0938	added acid to model			
			0940	16.00	18.00	2.00	bl.gr.
			0940	16.00	19.40	3.40	yellow
			1015	01.70	03.70	2.00	bl.gr.
			1015	01.70	05.30	3.60	yellow
1030		model behavior still strange; located trouble in open loft windows which produced a steady draft over model; closed windows	1110	06.95	09.10	2.15	bl.gr.
			1110	06.95	10.30	3.35	yellow
			1123	10.60	12.60	2.00	bl.gr.
			1123	10.60	13.90	3.30	yellow
1202	6 mo	equilibrium identical with 10 Oct. 1949 experiment	1205	14.50	16.50	2.00	bl.gr.
			1205	14.50	18.10	3.60	yellow
1224	202 da	start 35 mm at 0 exp. dark slide not withdrawn by oversight					
1224	202 da	start 16 mm at 0 ft. f-6.3					
1227	205 da	exp. 21 Leica 1/8 sec. f-11					
1229	207 da	discovered dark slide still in 35 mm camera, withdrew at 50 exp.					
1232	210 da	exp. 22 Leica 1/8 sec. f-11					
1248	225 da	exp. 23 Leica 1/8 sec. f-11	1250	18.45	20.70	2.25	bl.gr.
			1250	18.45	22.00	3.55	yellow
1300		replaced base bottle with an acid bottle since chemist reported the trace $CaCO_3$ in model plaster provides enough alkali in acid solution					

			Sample time	ml.stand.acid		△	end point
				initial	final		
COCC							
1304	240 da	exp. 24 Leica 1/8 sec. f-11					
1310	246 da	exp. 25 Leica 1/8 sec. f-11	1323	04.00	06.20	2.20	bl.gr.
			1323	04.00	07.60	3.60	yellow
1326	263 da	exp. 26 Leica 1/8 sec. f-11					
1330	267 da	exp. 27 Leica 1/8 sec. f-11					
1330	267 da	secured 35 mm at 535 exp.					
1330	267 da	" 16 mm at 98 ft. test confirms 10 October 1949 and shutter worked well; synchronized 1 sec. late					
CSRCC			1337	07.80	10.00	2.20	bl.gr.
			1337	07.80	11.00	3.00	yellow
1338	0 da	start SR wind					
1338	0 da	start 35 mm at 535 exp. 1/10 f-10					
1338	0 da	start 16 mm at 0 ft. f-6.3					
1339	1 da	exp. 28 Leica 1/8 sec. f-11					
1344	7 da	exp. 29 Leica 1/8 sec. f-11					
1351	14 da	exp. 30 Leica 1/8 sec. f-11					
1358	21 da	exp. 31 Leica 1/8 sec. f-11					
1406	28 da	exp. 32 Leica 1/8 sec. f-11					
1409	31 da	secured 35 mm at 800 exp.					
1409	31 da	" 16 mm at 48 ft.					
CWRCC							
1436	-½ da	start 35 mm at 0 exp. 1/10 sec. f-10					
1436	-½ da	start 16 mm at 47 ft. f-6.3					
1437	0 da	start WR wind					
1440	3 da	exp. 33 Leica 1/8 sec. f-11	1440	00.25	02.70	2.45	bl.gr.
			1440	00.25	04.30	4.05	yellow
1444	7 da	exp. 34 Leica 1/8 sec. f-11	1446	04.30	06.70	2.40	bl.gr.
1452	14 da	exp. 35 Leica 1/8 sec. f-11					
1453	15 da	exp. 36 Leica 1/8 sec. f-11 (clock)					
1502	24 da	exp. 1 Leica 1/8 sec. f-11					
1506	28 da	exp. 2 Leica 1/8 sec. f-11					

CWRCC			Sample time	ml.stand.acid initial	final	△	end point
1510	32 da	secured 35 mm at 250 exp.					
1510	32 da	" 16 mm at 95 ft.					
CNECC							
1510	0 da	start NE wind					
1525	15 da	start 35 mm at 250 exp. 1/10 f-10					
1525	15 da	start 16 mm at 0 ft. f-6.3					
		suspect adjustments of NE wind blowers disturbed equilibrium, will run additional 10 days to assure correct equilibrium	1526 1526	07.15 07.15	09.20 10.50	2.05 3.35	bl.gr. yellow
1526	16 da	exp. 3 Leica 1/8 sec. f-11					
1531	21 da	exp. 4 Leica 1/8 sec. f-11					
1538	28 da	exp. 5 Leica 1/8 sec. f-11					
1545	35 da	exp. 6 Leica 1/8 sec. f-11					
1551	40 da	exp. 7 Leica 1/8 sec. f-11					
1551	40 da	secured 35 mm at 450 exp.					
1551	40 da	" 16 mm at 40 ft.					
CNCC							
1552	0 da	start N wind					
1607	15 da	start 35 mm at 450 exp. 1/10 f-10					
1607	15 da	start 16 mm at 40 ft. f-6.3					
1608	16 da	exp. 8 Leica 1/8 sec. f-11	1610 1610	13.20 13.20	15.20 16.55	2.00 3.35	bl.gr. yellow
1613	21 da	exp. 9 Leica 1/8 sec. f-11					
1620	28 da	exp. 10 Leica 1/8 sec. f-11					
1623	31 da	secured 35 mm at 590 exp.					
1623	31 da	" 16 mm at 65 ft.					
CNWCC							
1624	0 da	start NW wind					
1638	15 da	start 35 mm at 590 exp. 1/10 sec. f-10					
1638	15 da	start 16 mm at 65 ft. f-6.3					
1640	17 da	exp. 11 Leica 1/8 sec. f-11	1640 1640	16.70 16.70	18.70 20.10	2.00 3.40	bl.gr. yellow

			Sample time	ml.stand.acid initial	final	△	end point
CNWCC							
1644	21 da	exp. 12 Leica 1/8 sec. f-11					
1652	28 da	exp. 13 Leica 1/8 sec. f-11					
1659	35 da	exp. 14 Leica 1/8 sec. f-11					
1700	36 da	secured 35 mm at 750 exp.					
1700	36 da	" 16 mm at 95 ft.					
CWCC							
1700	0 da	start W wind					
1713	13 da	start 35 mm at 0 exp. 1/10 f-10					
1713	13 da	start 16 mm at 0 ft. f-6.3					
1714	14 da	exp. 15 Leica 1/8 sec.	1714	20.20	22.30	2.10	bl.gr.
		f-11	1714	20.20	23.70	3.50	yellow
1721	21 da	exp. 16 Leica 1/8 sec. f-11					
1728	28 da	exp. 17 Leica 1/8 sec. f-11					
1731	31 da	secured 35 mm at 150 exp.					
1731	31 da	" 16 mm at 29 ft.					
CSWCC							
1732	0 da	start SW wind					
1744	13 da	start 35 mm at 150 exp. 1/10 f-10					
1744	13 da	start 16 mm at 30 ft. f-6.3					
1745	14 da	exp. 18 Leica 1/8 sec. f-11	1747	01.80	03.90	2.10	bl.gr.
			1747	01.80	05.15	3.35	yellow
1753	21 da	exp. 19 Leica 1/8 sec. f-11					
1800	28 da	exp. 20 Leica 1/8 sec. f-11					
1804	32 da	secured 35 mm at 300 exp.					
1804	32 da	" 16 mm at 60 ft.					
CSCC							
1805	0 da	start S wind					
			1816	06.20	08.30	2.10	bl.gr.
			1816	06.20	09.90	3.70	yellow
1818	13 da	start 35 mm at 150 exp. 1/10 sec. f-10					
1818	13 da	start 16 mm at 60 ft. f-6.3					
1819	14 da	exp. 21 Leica 1/8 sec. f-11					
1825	20 da	exp. 22 Leica 1/8 sec. f-11					

12 October 1949 TEST C' _ CC (continued)

CSCC			Sample time	ml.stand.acid initial	final	Δ	end point
1826	21 da	exp. 23 Leica 1/8 sec. f-11					
1833	28 da	exp. 24 Leica 1/8 sec. f-11					
1836	31 da	secured 35 mm at 450 exp.					
1836	31 da	" 16 mm at 95 ft.					

yellow average $\frac{9.94 \times 50}{2.14} =$ 1 part / 234

bl.gr. average $\frac{9.94 \times 50}{3.48} =$ 1 part / 143

median = 1 part / 189

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

13 October 1949 TEST C _ M

Bleed water discharge from all points (including dilution canal) characteristic of 1946 operations.

COM			Sample time	ml.stand.acid		Δ	end point
				initial	final		
		fresh water discharge 166 cc/min. ≋ 450 x 10^6 ft.^{3}/day; bleed water discharge 4^m 44^s/rev. ≋ 3.7 x 10^6 gal./day; dilution water discharge 40 drops/min. ≋ 40 x 10^6 gal./day; rotary bleed water proportioner in use; new 44 mm f-3.2 lens and Bolsey shutter in 35 mm Graflex	1020	07.30	09.50	2.25	bl.gr.
1021	-2 da	start 35 mm at 460 exp. 1/10 sec. f-10					
1021	-2 da	start 16 mm at 0 ft. f-6.3					
1023	0 da	bleed water discharge started					
1025	2 da	secured a little bleed water in feeder lines leaked out at -3 da; model flushed for new start					
COM							
1033	-½ da	start 35 mm at 500 exp. 1/10 sec. f-10					
1033	-½ da	start 16 mm at 10 ft. f-6.3					
1034	0 da	bleed water discharge started	1040	11.20	13.30	2.10	bl.gr.
			1040	11.20	14.90	3.70	yellow
1041	7 da	exp. 25 Leica 1/8 sec. f-11					
1048	14 da	exp. 26 Leica 1/8 sec. f-11					
1055	21 da	exp. 27 Leica 1/8 sec. f-11					
1102	28 da	exp. 28 Leica 1/8 sec. f-11					
1104	30 da	exp. 29 Leica 1/8 sec. f-11					
1113	39 da	reloaded 35 mm magazine					
1116	42 da	restarted 35 mm camera					
1119	45 da	exp. 30 Leica 1/8 sec. f-11					
1126	52 da	camera frame tilted west - leveled					
1133	58 da	reloaded 16 mm camera					

13 October 1949 TEST C _ M (continued)

COM			Sample time	ml.stand.acid		△	end point
				initial	final		
1135	60 da	exp. 31 Leica 1/8 sec. f-11	1135 1135	15.25 15.25	17.30 19.00	2.05 3.75	bl.gr. yellow
1136	61 da	restarted 16 mm camera					
1150	75 da	exp. 32 Leica 1/8 sec. f-11					
1205	90 da	exp. 33 Leica 1/8 sec. f-11					
1205	90 da	power plug pulled accidentally - resynchronized cameras					
1220	105 da	exp. 34 Leica 1/8 sec. f-11					
1235	120 da	exp. 35 Leica 1/8 sec. f-11					
1240	125 da	reloaded 16 mm camera					
1243	128 da	restarted 16 mm camera					
1250	135 da	exp. 36 Leica 1/8 sec. f-11	1250 1250	07.75 07.75	10.00 11.70	2.35 3.95	bl.gr. yellow
1250	135 da	exp. 37 Leica 1/8 sec. f-11 (clock)					
1258	143 da	reloaded 35 mm magazine					
1302	147 da	restarted 35 mm camera					
1305	150 da	exp. 3 Leica 1/8 sec. f-11					
1305	150 da	dilution water slows acid yellow 1 part in 710					
1320	165 da	exp. 4 Leica 1/8 sec. f-11					
1335	180 da	exp. 5 Leica 1/8 sec. f-11					
1346	191 da	secured 35 mm camera at 350 exp.					
1347	192 da	secured 16 mm camera at 95 ft.					
1350	195 da	exp. 6 Leica 1/8 sec. f-11					
CSRM							
1353	0 da	start SR wind					
1353	0 da	start 35 mm at 350 exp. 1/10 f-10					
1353	0 da	start 16 mm at 0 ft. f-6.3					
1353	½ da	exp. 7 Leica 1/8 sec. f-11	1355 1355	14.50 14.50	16.50 18.10	2.00 3.60	bl.gr. yellow
1400	7 da	exp. 8 Leica 1/8 sec. f-11					
1407	14 da	exp. 9 Leica 1/8 sec. f-11					
1414	21 da	exp. 10 Leica 1/8 sec. f-11					

CSRM			Sample time	ml.stand.acid		Δ	end point
				initial	final		
1421	28 da	exp. 11 Leica 1/8 sec. f-11					
1423	30 da	exp. 12 Leica 1/8 sec. f-11					
1424	31 da	secured 35 mm at 600 exp.					
1424	31 da	" 16 mm at 47 ft.					
1425		began return to no-wind equilibrium					
1600		no-wind equilibrium mainly reestablished					
CWRM							
1602	0 da	start WR wind from 1600 stage					
1614	12 da	start 35 mm at 610 exp. 1/10 sec. f-10					
1614	12 da	start 16 mm at 48 ft. f-6.3					
1616	14 da	exp. 13 Leica 1/8 sec. f-11					
1623	21 da	exp. 14 Leica 1/8 sec. f-11					
1630	28 da	exp. 15 Leica 1/8 sec. f-11					
1639	37 da	exp. 16 Leica 1/8 sec. f-11					
1641	39 da	reloaded 35 mm magazine					
1644	43 da	restarted 35 mm camera					
1646	45 da	exp. 17 Leica 1/8 sec. f-11					
1649	48 da	reloaded and restarted 16 mm camera	1650	01.70	03.70	2.00	bl.gr.
			1650	01.70	05.10	3.40	yellow
1651	49 da	exp. 18 Leica 1/8 sec. f-11					
1658	56 da	exp. 19 Leica 1/8 sec. f-11					
1702	60 da	exp. 20 Leica 1/8 sec. f-11					
1702	60 da	secured 35 mm at 150 exp.					
1702	60 da	" 16 mm at 20 ft. prolonged this run to get past cycle of asymmetrical tides					
CNEM							
1704	0 da	start NE wind					
1716	12 da	start 35 mm at 150 exp. 1/10 sec. f-10					
1716	12 da	start 16 mm at 20 ft. f-6.3					
1718	14 da	exp. 21 Leica 1/8 sec. f-11					

			Sample time	ml.stand.acid		△	end point
CNEM				initial	final		
			1720	05.40	07.35	1.95	bl.gr.
			1720	05.40	09.00	3.60	yellow
1725	21 da	exp. 22 Leica 1/8 sec. f-11					
1732	28 da	exp. 23 Leica 1/8 sec. f-11					
1736	33 da	secured 35 mm at 305 exp.					
1736	33 da	" 16 mm at 50 ft.					
CNM							
1745	0 da	start N wind, went to supper					
1845	60 da	start 35 mm at 305 exp. 1/10 sec. f-10					
1845	60 da	start 16 mm at 50 ft. f-6.3					
1845	60 da	exp. 24 Leica 1/8 sec. f-11					
			1850	09.50	11.66	2.10	bl.gr.
			1850	09.50	12.70	3.20	yellow
1852	67 da	exp. 25 Leica 1/8 sec. f-11					
1859	74 da	exp. 26 Leica 1/8 sec. f-11					
1906	81 da	exp. 27 Leica 1/8 sec. f-11					
1906	81 da	secured 35 mm at 480 exp.					
1906	81 da	" 16 mm at 83 ft.					
CNWM							
1907	0 da	start NW wind					
1921	14 da	start 35 mm at 480 exp. 1/10 sec. f-10					
1921	14 da	start 16 mm at 0 ft. f-6.3					
1921	14 da	exp. 28 Leica 1/8 sec. f-11					
			1925	13.00	15.00	2.00	bl.gr.
			1925	13.00	16.20	3.20	yellow
1928	21 da	exp. 29 Leica 1/8 sec. f-11					
1935	28 da	exp. 30 Leica 1/8 sec. f-11					
1939	32 da	secured 35 mm at 620 exp.					
1939	32 da	" 16 mm at 27 ft.					
CWM							
1940	0 da	start W wind					
			1953	16.40	18.40	2.00	bl.gr.
			1953	16.40	20.00	3.60	yellow
1954	14 da	start 35 mm at 620 exp. 1/10 sec. f-10					
1954	14 da	start 16 mm at 27 ft. f-6.3					

CWM			Sample time	ml.stand.acid		△	end point
				initial	final		
1954	14 da	exp. 31 Leica 1/8 sec. f-11					
2001	21 da	exp. 32 Leica 1/8 sec. f-11					
2008	28 da	exp. 33 Leica 1/8 sec. f-11					
2012	32 da	secured 35 mm at 760 exp.					
2012	32 da	" 16 mm at 54 ft.					
CSWM							
2013	0 da	start SW wind					
			2024	20,20	22.00	1.80	bl.gr.
			2024	20.20	23.85	3.65	yellow
2026	13 da	start 35 mm at 0 exp. 1/10 sec. f-10					
2026	13 da	start 16 mm at 55 ft. f-6.3					
2027	14 da	exp. 34 Leica 1/8 sec. f-11					
2034	21 da	exp. 35 Leica 1/8 sec. f-11					
2041	28 da	exp. 36 Leica 1/8 sec. f-11					
2041	28 da	exp. 37 Leica 1/8 sec. f-11; tide indicator-recorder string parted					
2045	33 da	secured 35 mm at 150 exp.					
2045	33 da	" 16 mm at 84 ft.					
CSM							
2047	0 da	start S wind					
2059	13 da	start 35 mm at 150 exp. 1/10 sec. f-10					
2059	13 da	start 16 mm at 0 ft. f-6.3					
2100	14 da	exp. 1 Leica 1/8 sec.	2100	24.40	26.40	2.00	bl.gr.
		f-11	2100	24.40	27.80	3.40	yellow
2107	21 da	exp. 2 Leica 1/8 sec. f-11					
2114	28 da	exp. 3 Leica 1/8 sec. f-11					
2119	33 da	secured 35 mm at 315 exp.					
2119	33 da	" 16 mm at 30 ft.					

yellow average $\frac{50.2 \times 50}{3.55} =$ 1 part / 710

bl.gr. average $\frac{50.2 \times 50}{2.05} =$ 1 part /1225

median = 1 part / 968

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

17 October 1949 FRESH WATER DISCHARGE

Progress of fresh water discharge from the northern watershed through the Barataria Bay estuary. Fresh water discharge rate set at 168 ^{cc}/min. ≅ 450 x 10^6 ft.^{3}/day.

1327	-5 da	Brom Cresol Green solution added to Little and Mud Lakes equivalent box
1332	0 da	start 35 mm at 310 exp., 1/10 sec. f-10
1332	0 da	start 16 mm at 30 ft., f-6.3
1337	5 da	added more Brom Cresol Green solution to equivalent box
1417	45 da	reloaded 16 mm camera
1422	50 da	changed record rolls on tide recorder
1435	64 da	added more Brom Cresol Green solution to equivalent box
1436	65 da	reloaded 35 mm magazine
1457	85 da	dye entered Lake Grande Ecaille area
1457	85 da	exp. 4 Leica 1/8 sec. f-11
1457	85 da	" 5 " " " "
1502	90 da	" 6 " " " "
1502	90 da	" 7 " " " "
1502	90 da	" 8 " " " "
1513	100 da	" 9 " " " "
1513	100 da	" 10 " " " "
1513	100 da	" 11 " " " "
1524	111 da	reloaded 16 mm camera
1532	120 da	exp. 12 Leica 1/8 sec. f-11
1532	120 da	" 13 " " " "
1532	120 da	" 14 " " " "
1532	120 da	" 15 " " " "
1534	122 da	" 16 " " " "
1534	122 da	secured 35 mm at 450 exp.
1534	122 da	secured 16 mm at 15 ft.

This run rejected because fresh water discharge rate dropped to 127 ^{cc}/min. without being noticed and because of drafts from open doors in waist of building.

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

18 October 1949 TEST AO

Progress of fresh water discharge from the northern watershed through the Barataria Bay estuary.

AO		fresh water discharge set at 163 ^{cc}/min. 450 x 10^6 ft.^{3}/day	fresh water discharge rate
1558	-1 da	Brom Cresol Green solution added to Little Lake equivalent box	163 ^{cc}/min.
1559	0 da	start 35 mm at 450 exp. 1/10 sec. f-10	
1559	0 da	start 16 mm at 15 ft., f-6.3	
1623	24 da	exp. 1 Leica 1/8 sec. f-11 (clock)	162 ^{cc}/min.
1627	28 da	exp. 2 Leica 1/8 sec. f-11	
1638	40 da	" 3 " " " "	
1645	47 da	reloaded 35 mm magazine	
1646	48 da	exp. 4 Leica 1/8 sec. f-11	
1648	50 da	" 5 " " " "	
1655	57 da	reloaded 16 mm camera	
1658	60 da	exp. 6 Leica 1/8 sec. f-11	158 ^{cc}/min.
1708	70 da	" 7 " " " "	163 ^{cc}/min.
1713	75 da	" 8 " " " "	
1720	82 da	" 9 " " " "	
1732	92 da	" 10 " " " "	
1735	97 da	" 11 " " " "	
1738	100 da	" 12 " " " "	
1746	108 da	" 13 " " " "	
1752	112 da	" 14 " " " "	
1758	120 da	" 15 " " " "	160 ^{cc}/min.
1758	120 da	" 16 " " " "	
1758	120 da	" 17 " " " "	
1758	120 da	" 18 " " " "	
1805	127 da	reloaded 16 mm camera	164 ^{cc}/min.
1813	135 da	exp. 19 Leica 1/8 sec. f-11	
1822	144 da	" 20 " " " "	
1828	150 da	" 21 " " " "	
1828	(clock)	" 22 " " " "	
1832	154 da	secured 35 mm at 800 exp.	160 ^{cc}/min.
1832	154 da	secured 16 mm time lapse at 45 ft.; ran off remaining film at 16 fr./sec. f-4.0	162 ^{cc}/min. average equivalent to 442 x 10^6 ft.^{3}/day

FREEPORT SULPHUR CO. BARATARIA BAY MODEL TESTS

18 October 1949 TRAVEL TIME TESTS ON EBB TIDE FROM POINT VI

An attempt was made to discharge Carter's midnight black ink for 1 model "hour" (2.5 sec.) from Point VI on Humble Canal at the beginning of slack ebb. It was hoped that such a dye in clear water would cohere enough to give some measure of the earliest arrival of bleed water in northern Bay Rouquille. The ink solution was not sufficiently coherent to represent parcel motion but only that of a certain finite dilution, hence these experiments reveal arrivals at a dilution that is very great but unknown. Discharge pulses liberated from Point VI at slack ebb during maximum symmetrical tides of tropic sequence.

VI A_1^T
1032 0 hr exp. 17 Leica 1/8 f-11
exp. 18-36 at 3 "hour" intervals thereafter, i.e., every 7.5 sec. mean solar time

VI A_2^T
1045 0 hr exp. 1 Leica 1/8 f-11
exp. 2-20 at 3 "hour" intervals thereafter

VI A_3^T
1107 0 hr exp. 1 Leica 1/8 f-11
exp. 2-20 at 3 "hour" intervals thereafter; some faint color reached west end of Lake Grand Ecaille on surface (tension?)

VI A_4^T
1115 0 hr exp. 1 Leica 1/8 f-11
exp. 2-20 at 3 "hour" intervals thereafter; some surface film again reached west end of Lake Grand Ecaille

APPENDIX III

The following pages are photographs of a series of 41 drawings representing the continuous and intermittent distribution of simulated bleed water observed in the Barataria Bay model during the condition B and C model tests. The boundaries of the areas were obtained from separate examination of each of the approximately 13,000 double 35 mm frames on the films exposed in the Graflex Photorecord camera. This camera recorded the distribution of simulated bleed water 8 times every model "day," that is, every 3 model "hours" throughout the model tests. The examination was performed by projection of the film strips on base charts prepared from a rubbing of the model. Each successive projected image was made first to coincide with the base chart and then the areas showing the yellow or green color of unneutralized acid were shaded in pencil and the boundaries drawn as a sharp line. The envelopes of all the outermost boundary lines of the several tests and their summaries are presented in the finished drawings that follow.

1. Summary of the distribution of color in all M and CC tests.

2. B __ M summary 3-11
3. B O M
4. B SR M
5. B WR M
6. B NE M
7. B N M
8. B NW M
9. B W M
10. B SW M
11. B S M

12. B __ CC summary 13-21
13. B O CC
14. B SR CC
15. B WR CC
16. B NE CC
17. B N CC
18. B NW CC
19. B W CC
20. B SW CC
21. B S CC

22. C __ M summary 23-31
23. C O M
24. C SR M
25. C WR M
26. C NE M
27. C N M
28. C NW M
29. C W M
30. C SW M
31. C S M

32. C __ CC summary 33-41
33. C O CC
34. C SR CC
35. C WR CC
36. C NE CC
37. C N CC
38. C NW CC
39. C W CC
40. C SW CC
41. C S CC

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Appendix I Schedule of procedure in model tests
II Photographic and Chemical log
III Drawings of results of model tests
IV Tide records attached to Copy No. 1. The tides are also indicated on the time-lapse motion and still pictures of the model tests
V U. S. Weather Bureau reports from Grand Isle, Louisiana station attached to Copy No. 1

I. SUMMARY - INTRODUCTION

In late December 1948, the Freeport Sulphur Company requested the writer to undertake construction of an hydraulic model of the Barataria Bay area in which their Lake Grande Ecaille, Louisiana, mine is located (see frontispiece adapted from Chart 1273 U.S.C.& G.S.). In this area, roughly 25 miles square, the characteristic depth of water is about three feet, necessitating either a very large model or a highly distorted smaller model. It was decided to make the model eight feet square, and employ a horizontal scale of 1/20,000 and a vertical scale of 1/192; that is, employ a vertical exaggeration of 1/104. The model was built and operated on the property of the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts.

The model was constructed on a strong bed of 2 x 12-inch fir timbers (fig. 1) arranged to form a tight network of triangular voids. The framework was then covered with 3/4 inch marine plywood in steps (fig. 2) so cut that the treads had the shape of the intervals between successive 12-foot contours on the bottom topography in the prototype (fig. 3). This "staircase" was boxed in by a heavy combing, caulked, (fig. 4) and covered with a lath of hardware cloth (fig. 5). Over this a 4-inch thickness (3/4 ton) of Hydrocal B-11 (precision pattern-maker's $CaSO_4$ plaster) was cut as a monolith in which the intricate modeling of the bays and islands could be cut with rotary tools. The layout of the land and islands

was projected from the top of a tower (fig. 6) at a height of 16 feet above the model surface, traced off, (fig. 7), and routed in relief (fig. 8) so that sea level lay 1/4 inch below the land surface. The soundings were then entered on the sea level surface from the same lantern slide and projector, and additional soundings were entered from the original data sheets provided by the U. S. Coast & Geodetic Survey. Soundings were realized by routing between carefully drawn contours (fig. 9). The steps were then blended with hand tools (fig. 10). The resulting surface (fig. 11) is probably accurate to ± 0.015 inch (± 0.25 "foot") vertically and ± 0.03 inch (± 50 "feet") horizontally. Sea level was established as a level plane (± .005-inch) by means of repeated checks with a precise transit on the pair of rails from which the routing tools were suspended.

Gravitational (Froude) scaling of the kinematic ratios of time, velocity and discharge was used unmodified except at the passes connecting the bays with the Gulf of Mexico. In each of the passes the velocity and the turbulence (measured in terms of eddy diffusion) of flow were initially too high. In order to correct this common situation, roughness was artificially increased in the passes by means of wire screens (20 x 20 mesh). Increased roughness in these critical channels not only decreased the velocities so as to agree with the Froude scales but corrected to an acceptable degree the characteristics of channel turbulence as well. To verify the over-all kinematic behavior of

the flooded model, as many hydraulic occurrences as possible were compared with data from the detailed field reports of H. A. Marmer,[1] and observations by V. H. Brogdon and the writer. With few adjustments of the model the times of slack water, the occurrence of high and low water, the particle excursions, and magnitudes of velocities were reproduced at a large number of points.

Auxiliary equipment was designed to reproduce tides, winds, rainfall and industrial discharge scaled in accordance with the model constants.

The tide machine was composed of three drums, each of which displaced water and changed sinusoidally the water level in the model at rates in accordance with the time scale 1/1440 (one minute per model "day"). Each drum was driven by a scotch yoke through a stroke of 2 inches; the semi-diurnal drum having a displacement determined by the sum of the amplitudes of the M_2, S_2 and N_2 tidal components and a speed number of the average of the component speed numbers, the first diurnal drum a displacement determined by the amplitude of the O_1 tidal component and a speed number of the O_1 component, and the second diurnal drum a displacement proportional to the sum of the K_1 and P_1 tidal components and driven at the

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[1] The Tide in Barataria Bay, U. S. Coast & Geodetic Survey, Washington, D. C., July 1947.

The Currents in Barataria Bay, U. S. Coast & Geodetic Survey, Washington, D. C., February 1948.

average speed of these two which is precisely a mean solar day per 360°. Thus, the second diurnal drum was run at one cycle per minute and the other two at 30.5 seconds and 64.5 seconds per cycle respectively. This combination produced a succession of great diurnal tides yielding to lesser semi-diurnal tides at intervals of about two "weeks," a progression characteristic of this region of the Gulf of Mexico (fig. 12).

The winds were generated by tank-type vacuum cleaner blowers mounted around the model at the cardinal and intercardinal points. Each was wired to a switch at a central control point and its rate of pumping governed by a Variac. Thus, it was possible to vary the wind speed and direction to reproduce either the detailed or average wind as it occurred during the periods of interest to the sponsors and in accordance with the records of the U. S. Weather Bureau reports from Grand Isle, Louisiana.[2/] Velocity calibration of the wind machines was accomplished by observing the rate at which the surface layer of water in the model was propelled under wind stress at the steady state. It was assumed on the basis of field experience and values derived from empirical equations for wind stress that in more than 10 miles of fetch the stress on the surface is such as to produce an equilibrium surface current speed between 2 to 3% of the wind speed.[3/] By this

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2/ See Appendix V attached to Copy No. 1.

3/ Sverdrup, Johnson & Fleming, The Oceans, Prentice Hall, New York, 1942, pp. 489-503.

measure, it was possible to produce winds of hurricane force (100 "knots") from the simultaneous draught of three blowers running at full speed. Due to the small horizontal scale and the vertical exaggeration of the model, the capillary wave height was too small and the capillary wave length was too large for wave action to be in scale or to produce the significant mixing effects found in nature.

Rainfall, which amounts to 60 inches per year on a watershed of some 1100 square miles to the north of the modeled area, drains through the modeled area at the rate of approximately 450,000,000 cubic feet per day, according to Marmer.[4/] This flow was introduced in the Little Lake equivalent box at the northwest end of the model by means of a pump attached to the tide machine. This pump drew water from the Gulf and produced both a closed circulation system for the rainfall, and a current of water through a venturi which generated a slow longshore current moving westward along the coast in agreement with known offshore circulation.

Industrial wastes (also referred to as bleed water) were introduced into the model through copper tubes embedded in the plaster and terminated at their proper geographical positions on the Freeport Sulphur Company properties. The injection ends of the tubes were attached to open glass cups at the level of the water in the model.

[4/] The rainfall on the modeled area was disregarded.

Each cup was supplied at first by a calibrated dropper and later on by the outlet of a proportioning funnel, both of which in turn being fed by a 100 cc hypodermic syringe acting as a positive displacement pump closed by a motor-driven screw. Thus, it was possible to know and control the quantities of industrial waste being introduced into the model either by counting drops delivered per minute from calibrated dropper tips or by timing the revolutions of the motor-driven screw. The industrial waste was simulated by an acid. The acid concentration chosen was such that when it mixed with a given number of volumes of ambient model water, containing an indicator solution of brom cresol green, it changed color from yellow to blue. The model water was set chemically to a known alkaline state (blue) such that for a given acid strength the color change (yellow-blue) would occur at a predetermined dilution. In this way the industrial waste, more concentrated than any specified dilution figure was represented by yellow water, and further dilutions in excess of those specified by a pleasing blue color which pervaded the whole model and varied in intensity with the depth of water.

Under certain conditions, continued discharge of industrial waste eventually extended unneutralized acid boundaries into the Gulf portion of the model. If routine titration of samples of water drawn from the Gulf showed it necessary, as the unneutralized acid reached and mixed away in the Gulf, a base of identical strength was introduced volume for volume into the Gulf at the

circulating venturi. In this way the ambient water in the Gulf volume was rendered chemically infinite and was maintained quantitatively in its alkaline condition. Thus the model could be run indefinitely to study the steady states of waste distribution in the bays under a variety of controlled conditions.

The results of the model studies were recorded automatically in color photographs made simultaneously with each of two cameras (1) a 35 mm Graflex pneumatic microfilming camera operated once every 7.5 seconds producing 8 exposures per model "day" and (2) a 16 mm Bolex time-lapse motion-picture camera operated electrically at 1 exposure every second yielding 60 exposures per model "day" and effecting a contraction of time, when projected at 16 frames per second, of 1/23040, that is, of 1 model "day" per 3.75 mean solar seconds. Light for photography was provided by 12 No. 2 photoflood lamps in reflectors, a total of 6000 watts illumination in controllable quantities for uniform lighting. An electric clock fitted with a dial graduated in 24 model "hours" swept by the second hand, 60 "days" indicated by the minute hand, and 24 "months" indicated by the hour hand, was mounted in the field of view of both cameras so that the elapsed time from the beginning of each experiment was automatically indicated and totalized. Similarly the contribution of each of the tide drums was integrated and the sum of their effects indicated by a traveling pointer on a scale large enough for the cameras to record the height of water to 0.05 scale "foot." The same integrator was coupled to a pen

which wrote a record of the tides on a paper tape moving at 1/2 inch per minute (fig. 12, and completely represented in Appendix IV of Copy No. 1 only). The wind direction was indicated by a small banner on a circular card placed on an island (unnamed) near the center of the model. In "no wind" conditions this indicator was removed from the model.

The tests of the model consumed approximately 65,000 model "hours" (about seven and one-half model "years") and were recorded in color on approximately 13,000 frames of 35 mm film strip and 3,000 feet of 16 mm time-lapse motion-picture film. The bulk of this record has been reduced to a series of 41 summary drawings (Appendix III) representing the continuous and intermittent (tidal) excursion of the simulated industrial waste in the model for each wind condition in each of two major bleed water discharge conditions, Tests B and C, and two concentration conditions, nominally 1:1000 and 1:200. Test A, which shows the distribution of fresh water drainage through the model area, is most easily seen in the original 16 mm time-lapse motion picture. However, figure 13 shows a characteristic stage after 30 "days" advance of fresh water into Barataria Bay from the north. This circulation of fresh water drainage undoubtedly tends to block the otherwise free circulation of water from Lake Grande Ecaille into Barataria Bay.

II. THE ROLE OF MODERN HYDRAULIC MODELS

Hydraulic models as they are understood and employed today are the product of several decades of experimental development. There are no comprehensive mathematical relationships to express the entire range of correspondence between models and their prototypes. Lacking these, the design and operation of hydraulic models is an art and the results obtained are necessarily subject to interpretation. The process of interpretation is frequently qualitative or categorical in the "is" or "is not" sense since a full accounting of all the physical properties of a fluid system is not always possible. Within these limitations, however, the use of models has great interpretive value. Today, most important problems in fluid engineering are solved through combined consideration of model experiments and mathematical analysis of the known physical factors.

The function of a model is essentially that of an analogue computer. When a geometrically extensive or lengthy series of hydraulic events involves a great number of complex factors it is too difficult for the human mind and too laborious for exact mathematical analysis to cope with them all simultaneously. Usually, more intelligible results can be obtained if a similar system is constructed and studied under controlled laboratory conditions.

The degree of similarity between a model and its prototype

may be only geometrical, or it may be kinematic, or dynamic. Two structures are said to be geometrically similar if the ratios of all homologous dimensions are equal. Kinematic similarity is similarity of motion. The motions of kinematically similar systems are geometrically similar and the ratios of the velocities of the several homologous particles in motion are equal. Few models are similar to a higher degree. It is possible, however, for two systems to possess dynamic similarity either in certain or all respects. In order to achieve dynamic similarity the two systems must be kinematically similar and in addition the ratios of the homologous masses and forces concerned in the motion must be equal. The condition of complete dynamic similarity is seldom achieved except in instances where the model is identical with the prototype in every respect.

III. THE SCALES OF THE BARATARIA BAY MODEL

The scales of the Barataria Bay model are based primarily on the equations of kinematic similarity due to Froude. These equations concern the relationships between gravitationally energized fluid systems in a state of continuous quasi-hydrostatic equilibrium. In an estuary like Barataria Bay there are two dominantly gravitational factors controlling the circulation; the tides and the drainage of rainfall. Wind stress is also present and scaled to the model since it produces very significant water motions, but since this force is not gravitational its scaling transcends kinematic relationships.

Once the similarity of circulation in the main bodies of water is established in a model it is possible to introduce an indicator to trace the progress of suitably scaled quantities of industrial discharge under a variety of simulated natural conditions. This was the purpose for which the Barataria Bay model was built.

The notation used in scaling relationships is similar to ordinary physical notation except that all symbols that apply to the prototype are followed by a subscript "p" and those applying to the model are followed by a subscript "m." Scaling ratios are usually dimensionless and followed by a subscript "r" defined for any quantity J as

$$J_r = \frac{J_m}{J_p} . \qquad (1)$$

It is possible to assign J_m unit value and express J_p as its multiple. Thus the time scale in a model compressing the events of one mean solar day within the compass of one mean solar minute; $T_r = T_m/T_p = 1/1440$. The units of the ratio cancel mathematically but if they are preserved the scaling ratio expresses, instance for instance, the proportion in common units of the homologous quantity in either the model or the prototype. In the case illustrated one may justly speak and think interpretatively of a model "day" but this interval is still only one mean solar minute for purposes of calculation.

Choice of the vertical and horizontal scales was determined for the Barataria Bay model by the dimensions of the available space, the vertical distortion required to maintain a useful depth of water and by the rate of going of the model. Because of the complexity of the water-land areas in the Barataria Bay region it was considered imprudent to build the model on a horizontal scale smaller than 1/20,000. This horizontal scale allows all the area of interest to the sponsors and the additional areas containing significant influences of oceanographic and hydrologic kinds, except part of Little Lake, to be included in a space eight by eight feet. The remainder of Little Lake was represented by a box of equivalent area mounted on the outside of the model at

the northwest corner and connected to the fluid system by a tunnel of suitable dimensions. The horizontal scale being thus fixed, and considering the desirability of a time scale of one mean solar minute per mean solar day, the vertical scale was calculated from the kinematic formula of Froude for the distorted open channel model in which the value of g and properties of water are substantially the same for the model and the prototype.

$$y_r = \left(\frac{L_r}{T_r}\right)^2 = \frac{1}{193} \tag{2}$$

This vertical scale is within half of one per cent of 1/16 inch per "foot" and was so adopted. The resulting vertical distortion is

$$D_v = \frac{L_r}{y_r} = \frac{192}{20,000} = \frac{1}{104} \tag{3}$$

This amount of vertical distortion is acceptable.

The Froude velocity scale is derived from consideration of the rate of progress of a gravity wave of very great length compared with the depth of water; that is of tidal dimensions. The rate of progress of such a wave is given by $\sqrt{g\ d}$, where g is the acceleration of gravity and d is the depth of water. The acceleration of gravity is substantially the same in both the model and prototype hence the velocity ratio is entirely controlled by the

square root of the vertical scale, $\sqrt{y_r}$. Thus

$$V_r = \sqrt{y_r} = 1/13.9 \qquad (4)$$

This means that a velocity of 1 knot in the prototype is represented in the model by a velocity of 1/13.9 knot or 3.65 cm/sec. Since the available data on the velocities of flow in the prototype were given in knots, a ruler was constructed and graduated in 3.65 cm intervals with tenths on one side and quarters on the other so that the velocities in the model might be checked with these lengths against the seconds beat of a break-circuit chronometer made audible through a loud speaker.

With the establishment of the time and length scales it was possible to calculate the discharge scale for the rainwater and bleed water. The kinematic discharge of rivers and industrial waste is scaled with regard to volume $\left[(L_r)^2\ y_r\right]$ per unit time (T_r). Since $T_r = L_r/\sqrt{y_r}$ the total discharge scale Q_r is

$$Q_r = \frac{(L_r)^2\ y_r}{\left(\dfrac{L_r}{\sqrt{y_r}}\right)} = L_r(y_r)^{3/2} = \frac{1}{5.3 \times 10^7} \qquad (5)$$

The discharge $Q_m = Q_r Q_p$ is the discharge into the model over the same interval of time as is expressed for the discharge in the prototype. To make this perfectly clear, if the discharge of a river is (10^n) m^3/mean solar day, the scaled discharge into the model must be $Q_r \times 10^n$ m^3/mean solar day, not per model "day."

The characteristic kinematic scaling factors used in the Barataria Bay model construction and operation are as follows:

L_r	horizontal length scale	1/20,000
y_r	vertical length scale	1/192
$D_v = L_r/y_r$	vertical distortion factor	192/20,000 = 1/104
$T_r = L_r/\sqrt{y_r}$	time scale	1/1440 = 1 min./"day"
$V_r = \sqrt{y_r}$	velocity scale	1/13.8(3) = 3.65 cm/sec/"kt"
$Q_r = L_r(y_r)^{3/2}$	discharge scale (total)	1/53,000,000
ρ_r	kinematic density scale	1/1
$U_r = 0.025\ V_r$	wind scale	(empirical calibration)

The approximate physical dimensions of the Barataria Bay model are given to provide some acquaintance with the scale of the model experiments. About six months of effort by sixteen part- and full-time craftsmen were required to build the model and its auxiliary equipment.

over-all north-south length of modeled surface	8.0 feet
over-all east-west length of modeled surface	8.0 feet
maximum depth in Gulf portion	0.5 feet
Characteristic depth in Barataria Bay/-Grande Ecaille portion	0.04 foot
height of land above msl.	0.02 foot
material routed away to form modeled surface	600 lbs.
volume of water in system	20 cubic feet
weight of flooded model	2000 lbs.
dimensions of model working space	20 x 20 x 20 feet
volume of model and auxiliary equipment	3000 cubic feet
electric motors (synchronous)	4
electric motors (controllable speed)	12
power consumption (lighting)	6000 watts
power consumption (total mechanical)	7500 watts

IV. RECONCILIATION OF KINEMATIC AND DYNAMIC PROCESSES

The considerations preceding the table of scales have not included the scaling of density and wind velocity. The scaling of density influences mixing, which is essentially a dynamic process, and the scaling of wind velocity involves several considerations which are most accurately reconciled by an empirical process in the present state of the model making art.

Density scales:-[5] The circulation in estuaries frequently involves the mixing of two or more water masses of different density. In direct kinematic (Froude) scaling these density differences should be maintained 1/1 in a model. The 1/1 scale of densities leads to satisfactory results if the problem involves only the kinematics of incursion. If, for instance, a large mass of salt water flows in from the sea under fresh water as in a lagoon or estuary, the velocities, volumes and times of arrival of the main water masses are correct, but the mixing of the two water masses is usually quite dissimilar and unrealistic. The water masses tend to retain their identity too long in the model and to stratify. This result is inevitable, for a fractional scale kinematically similar model can rarely be made to possess a 1/1 ratio of both

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[5] While it is customary to consider density in model theory, it is usually simpler to measure specific gravity with respect to pure water at some standard temperature in experimental work. The specific gravity so measured is numerically equivalent to density.

Froude and Reynolds numbers with its prototype. In the scales of oceanographic models the Reynolds numbers of flow in the model are often several orders of magnitude lower than corresponding values in the prototype.

In the Barataria Bay model two instances of deficient mixing are potentially present due to stratification accompanying (1) the density difference between the predominantly fresh drainage of rainfall into the northwestern part of Barataria Bay via Bayou St. Denis and Grand Bayou, and (2) the density difference between the ambient water of the Barataria Bay-Lake Grande Ecaille system and bleed water. Since there is at present no useful simultaneous solution to the problem of combined Froude and Reynolds density scales a choice was made in the first case in favor of the reciprocal Reynolds scale for increased realism of the circulation, and in the second to abide with the unmodified Froude scale since the injected volumes of bleed water exert a truly insignificant effect on the circulation.

The density difference between fresh water drainage and the ambient density of Barataria Bay water is amply sufficient to cause the fresh water to float on the surface of the ambient water as a thin but very extensive sheet. This tendency exists in nature to the same extent but it is overcome by the mixing processes associated with higher Reynolds numbers of flow, higher eddy diffusivity, and mixing by wave action.. In nature the several mixing processes carry the buoyant fresh water downward

to form a homogeneous vertical mixture and are so vigorous that they also carry bottom silt upward in sufficient quantities to maintain a high degree of turbidity. In order to reproduce these effects in a model it is necessary to reduce the work to be done by the existing turbulence and associated eddy diffusion. The work to be done is lessened by reducing the density difference empirically by an amount roughly equivalent to the vertical distortion. The necessary change of density difference was actually found to be about two orders of magnitude. This factor reduces the initially small density difference (0.012) to such an uncontrollably small magnitude (0.00012) that the desired condition is more reliably represented by a homogeneous system. Thus the small volume (165 cc/min.) required for the rainfall contribution was pumped from the very large Gulf of Mexico volume and piped into the Little Lake equivalent box attached to the northwest corner of the model. This method of closing the rainfall circulation produced less than 1 part in 2000 error in the tidal circulation and automatically maintained a constant mean sea level.

In the second case, that of the bleed water density scaling, the volumes are insignificant compared with the tidal exchange of the waters they enter, and as bleed water is heavier than the ambient water it tends to sink. While bleed water is about as much heavier than the ambient water per unit volume as the rain water is lighter, and could also be well approximated by a homogeneous fluid, it was considered a more conservative approach if

the 1/1 density differences indicated by Froude scaling were maintained.[6] This decision causes the simulated bleed water of the model to stratify and collect in depressions and practically to fill these depressions before traveling farther along. It also exaggerates the concentrations of bleed water by retarding its rate of mixing with the ambient water which would otherwise allow it to be carried away with greater rapidity and at greater dilution than the model indicates. When at length, under one-to-one density scaling conditions, the bleed water has reached the steady state of distribution and concentration and is mixing away at a rate equal to its rate of supply, the filaments of a given concentration are somewhat too long, too thin and somewhat too narrow because of the deficient Reynolds number of the flow and dissimilar eddy diffusivity of the gravity controlled kinematic model. It is significant, and a result of this choice, that the principal effect of wind on the bleed water tracer pattern in the model is to drive it upwind on the bottom. Both in nature and in the model there is a surface layer driven downwind which is usually somewhat thinner and more vigorous than the upwind counter current on the bottom. In nature wave action and more intense eddy diffusion would tend to mix vertically the contents of the two layers, that is, the bleed water accumulated in the bottom counter current

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[6] Question concerning the advisability of departing from Froude scaling arises only in connection with models of very shoal estuaries wherein wave action reaches to the bottom and wind circulation is important.

would be transported upward into the surface current and the uncontaminated surface water transported downward to dilute the concentrations present in the bottom counter current, and thus drive a more dilute solution of bleed water in both directions at once.

Wind velocity scales:- Wind stress on a model surface cannot be scaled from purely kinematic considerations because the factors concerned are primarily dynamic, and far from perfectly understood in nature. The transfer of energy by wind stress on the water surface involves considerations of at least the roughness of the interface, the temperature difference, temperature structures, eddy diffusivities, and densities of the two media, and probably the condition of the water surface skin. The surface roughness produced by simulated winds over small oceanographic models is usually too small due to the development of predominantly capillary waves rather than gravity waves. Capillary waves do not white-cap readily and they move faster as their lengths diminish while gravity waves move slower as their lengths diminish. Furthermore, to be in scale a modeled wave would have to have a scaled height y_r and a scaled length L_r in a distorted model. This latter requirement is often a physical impossibility. In view of all these difficulties it has been the practice to scale the model "wind" by scaling the translation effects it produces on the water surface. Oceanographic data indicate that where the fetch is greater than an equivalent of 5 to 10 thousand meters

and a steady state exists, an appreciable thickness of the surface water will be moving at a speed in the order of 2 to 3 per cent of the steady wind speed. In the Barataria Bay model the average steady wind speeds in each of the cardinal and intercardinal directions were computed from data supplied by the Grand Isle station of the U. S. Weather Bureau. The blowers were driven at the proper rate to produce a V_r scaled surface water motion equivalent to 2.5 per cent of the average wind speed wherever the fetch was great enough in each case. Every precaution was taken during the wind calibration and the model tests to have the model surface scrupulously clean so that the surface tension of the water skin maintained a uniform value and the rigidity of the skin was as low as possible. Before each test the surface was cleaned first by an ionic detergent and thereafter by a scummer. Tests were not begun until the detergent had had time to hydrolize and diffuse into the volumes of water below the surface. Since the action of the surface active agent is essentially monomolecular in thickness the resulting volume contamination was truly negligible.

The average wind velocities were calculated from statistics for the year 1946 prepared by the New Orleans Office, U. S. Weather Bureau, from observations made at Grand Isle, Louisiana, and are as follows:

	Wind direction symbol	Wind direction	Average wind speed (knots)	Water speed (knots)	Variac (volts)
Average spring-summer	WR	140°T	4.0	0.10	32.5
Average southeast wind	SE	135°T	9.0	0.22	41.0
Average autumn-winter	SR	085°T	7.8	0.20	39.0
Average east wind	E	090°T	10.0	0.25	40.0
Average northeast wind	NE	045°T	10.0	0.25	47.0
Average north wind	N	000°T	11.3	0.28	42.0
Average northwest wind	NW	315°T	9.5	0.24	41.0
Average west wind	W	270°T	8.9	0.22	39.0
Average southwest wind	SW	225°T	7.6	0.20	37.0
Average south wind	S	180°T	8.6	0.21	38.0

The direction of the average spring-summer wind being within 5° of southeast, the two directions were not distinguished and the higher average wind velocity was used as one test. The same distinction was omitted in the case of the average autumn-winter and the east wind which also differ in direction by 5°. Thus the actual wind velocities and directions used in the model tests were as follows:

	Wind direction symbol	Wind direction	Average wind speed (knots)	Water speed (knots)	Variac (volts)
"no wind" run to equilibrium	O	--	0.0	0.00	00.0
Spring-summer equilibrium	SR	140°T	9.0	0.22	41.0
Autumn-winter equilibrium	WR	085°T	10.0	0.25	40.0
Northeast wind equilibrium	NE	045°T	10.0	0.25	47.0
North wind equilibrium	N	000°T	11.3	0.28	42.0
Northwest wind equilibrium	NW	315°T	9.5	0.24	41.0
West wind equilibrium	W	260°T	8.9	0.22	39.0
Southwest wind equilibrium	SW	225°T	7.6	0.20	37.0
South wind equilibrium	S	180°T	8.6	0.21	38.0

The first three of these runs probably have greatest significance because they show first the action of the tides and rainfall in distributing the bleed water and then how the average conditions of the two major seasonal wind directions and forces influence this distribution. In nature the wind over Barataria Bay apparently does not often blow long enough from any of the non-prevailing directions to re-establish a corresponding equilibrium distribution of bleed water. Each of the wind runs in the model was carried through a little more than one semi-monthly change of the diurnal tide sequence. The equilibria represented in the films of the model undergo continuous cyclic modification as the contributions of the tidal, rainfall and wind circulation systems change in relative importance through a two-week period. The drawings of the results of these tests (Appendix III) show the accumulated greatest extension of bleed water pattern and do not represent the distribution at any one time. Distinction has been made between the continuous and intermittent distribution, some of which is tidal and some due to the changing direction and force of the winds.

V. THE TIDE MACHINE

The characteristic circulation in an estuary such as Barataria Bay is directly related to the daily and monthly sequence of tides. The design and calculations of the tide machine were taken from broader considerations than the tides observed in the estuary itself.

For proper representation of tidal currents in open coastline models the tide machine should be located offshore in the modeled portion of the sea. If possible it should be equidistant from all parts of the model coast line so that the cotidal lines of the wave will be initially parallel to the coast and thereafter altered by refraction as in nature. If it is known that the cotidal lines lie initially at some angle to the coast or are normal to it describing a progressive wave moving up or down the coast line, the tide machine and barriers should be located so as to simulate this approach. The more remote the position of the tide machine from the modeled embayment the more changed are the amplitudes of the tidal coefficients of the machine as they are amended to apply at the position offshore. Fortunately this amendment often allows simplification of the tide generator, for some of the important complicating constituents in the tidal records near the openings to estuaries are due to the behavior of a simple wave inside the estuary. Since the modeled estuary will provide these complicating effects of its own accord, they

should not be introduced twice. A good approximation of the final form of the offshore tide generator components can be obtained from a weighted average of the tidal coefficients at stations offshore or some distance away in both directions along the coast.

The complexity and rate of going of a tide generator varies with the character of the tidal trace both within and along the seaward margins of the prototype. The components of a tide machine are determined from the relative importance of each of the several tidal coefficients compared with their sum. Unimportant coefficients of the same tidal species can be collected and introduced as a single component driven at the weighted mean rate. Important species having speed numbers sufficiently close to this weighted mean can be added as well to simplify the mechanism. Separate components must be set apart if their amplitudes and speed numbers are such that they largely determine the characteristic sequence of tides. In middle latitudes near open sea coasts, the tides are predominantly semi-diurnal with more or less diurnal inequality and a semi-monthly sequence of ranges. If neither the diurnal inequality nor the semi-monthly range sequence is large, the tide can be closely approximated by a single drum of the proper displacement driven at the weighted mean rate of all the significant semi-diurnal species known for that station. If the diurnal inequality is too great to be neglected but the diurnal species are still unimportant, two semi-diurnal drums will suffice. If the diurnal species are important, and have a

strong semi-monthly sequence of amplitudes, or if the diurnal species are less important but not negligible, three drums will be required to produce an acceptable approximation of the tides. This is the case applicable to Barataria Bay.

The volume of water to be displaced in the model to effect the rise and fall of tides is the volume ratio $\left[(L_r)^2 y_r\right]$ times the volume change (tidal prism) in the flooded areas of the prototype. To calculate the displacements of the tide machine drums it is possible to prorate the scaled volume of the tidal prism among the important harmonic constituents in proportion to the ratio of their amplitudes to the sum of all terms. This process automatically includes and distributes the minor contributions of the neglected components.

The basic data for the Barataria Bay tide machine were taken from

1. Tidal Harmonic Constants (Atlantic Ocean) TH-1 Jan. 1942
   U. S. Department of Commerce, Coast and Geodetic Survey
2. Tide Tables (Atlantic Ocean) Ser. 671, 1946.
   U. S. Department of Commerce, Coast and Geodetic Survey

The two stations Pensacola, Florida and Galveston, Texas distantly flanking Barataria Bay were chosen as a combination which would be free of conspicuous estuarine resonance and the average signatures of which would be indicative of the characteristic tidal oscillations on the proximal parts of the continental shelf of the Gulf of Mexico. The average of the two sets

of harmonic coefficients was taken as a first approximation of the open water tidal condition near the coast.

	K_1	O_1	P_1	Q_1	M_2	S_2	N_2	K_2[7]
Pensacola (1934)	0.43	0.49	0.13	0.08	0.06	0.02	0.01	0.02
Galveston (1939)	0.38	0.35	0.10	0.08	0.31	0.10	0.08	0.01
2)	0.79	0.85	0.23	0.16	0.37	0.12	0.09	0.03
	0.39	0.43	0.12	0.08	0.19	0.06	0.05	0.01

Total range 1.24 feet

The small Q_1 and K_2 constituents were neglected as individuals and their contributions incorporated in the total displacement of the tide machine drums. Three drums were built and driven through a stroke of 2 inches at the following speeds:

	prototype	model	range	radius	displ.
K_1P_1 drum	24.00 hrs	60.0 sec.	0.51 "ft."	5.35 in.	181.0 in.^{3}
O_1 drum	25.82 hrs	64.5 sec.	0.43 "ft."	4.92 in.	152.2 in.^{3}
$M_2S_2N_2$ drum	12.21 hrs	30.5 sec.	0.30 "ft."	4.10 in.	106.0 in.^{3}
sum of all contributions			1.24 "feet"		440.2 in.^{3}

The final tests of this tide machine revealed errors of 3.2% in

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[7] See following page.

range and 15% in phase progress due to neglect of the longer period terms. The M_f and M_m constituents[7] were partly accounted for in rate adjustment of the O_1 and K_1P_1 drums.

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[7] K_1 = lunar declinational diurnal constituent, speed = $15^\circ.041$/m.s. hr.
O_1 = " " " " , speed = $13^\circ.943$/m.s. hr.
P_1 = solar " " " , speed = $14^\circ.959$/m.s. hr.
Q_1 = a lunar diurnal constituent , speed = $13^\circ.399$/m.s. hr.

M_2 = principal lunar semidiurnal constituent, speed = $28^\circ.984$/m.s. hr.
S_2 = principal solar semidiurnal constituent, speed = $30^\circ.000$/m.s. hr.
N_2 = larger lunar elliptic " " , speed = $28^\circ.440$/m.s. hr.
K_2 = luni-solar declinational semidiurnal " , speed = $30^\circ.082$/m.s. hr.

M_f = lunar fortnightly constituent , speed = $1^\circ.098$/m.s. hr.
M_m = lunar monthly harmonic constituent , speed = $0^\circ.544$/m.s. hr.

VI. KINEMATIC VERIFICATION OF THE MODEL

The effectiveness and reliability of an offshore tide machine in a model is best evaluated by comparison with the tide curves at the principal entrances to the estuary and against the accompanying velocities of flow and the times of slack with respect to high and low water in the prototype. These comparisons serve the additional purpose of verifying the kinematic similitude of the whole model.

The verification of the Barataria Bay model was considered consistent with the available data and acceptable when the sequences of times of slack water and maximum currents led or lagged the times of high and low water within one-half "hour" (1.25 sec.) of the times observed in the prototype by H. A. Marmer. Particle traverses were accepted when they agreed within $\frac{1}{4}$ "mile" of Marmer's predictions. Similarly the speeds and directions of the currents were accepted when they fell within less than one quarter "knot" of the speeds and 10° of the directions reported by Marmer in his reports on THE TIDE IN BARATARIA BAY and THE CURRENTS IN BARATARIA BAY. Further data on the details of the circulation around the Freeport Sulphur Company property were obtained by the writer or were supplied to him by V. H. Brogdon of the Freeport Sulphur Company. Particular attention was paid to the traverse of particles in Barataria Bay and to the asymmetry of duration of flood and ebb between St. Mary's point and the mouth of Bayou St.

Denis caused by the rain water drainage through the estuary. The latter is a distinguishing feature of the Barataria Bay circulation because it is indeed a river mouth of rather peculiar shape. Test A is concerned with a detailed study of rainfall drainage and its effect in tending to exclude the waters of both Lake Grande Ecaille and Bay Ronquille from Barataria Bay proper. In the eastern areas there is known to be an unusual division of the directions of ebb currents in the southern part of the Lake Washington system which causes the flood and ebb currents to diverge. Ebb currents flow north in part of Lake Washington and south in the region nearer Bay Chaland and reverse on the flood. The position of this division in the model was found to be in good agreement with field observations. Through the expedient of interposing the 20 by 20 mesh screens in the seaward passes the calculated rate of going of the tide machine was made acceptable. The calculated fresh water discharge through the Little Lake equivalent box led to a correct phase and duration of flood and ebb currents with respect to high and low water at Barataria Pass. Insofar as it is possible to estimate the reliability of a model with respect to field observations, the Barataria Bay model probably possessed a kinematic figure of merit of about 8 on a scale of 10. Since good quality field observations are generally rated at about this same figure of merit, and they alone reveal the behavior of the prototype, the estimated correspondence of the model to the true behavior of the prototype must be between 6

and 7 on a scale of 10. The higher figure is more likely in this case because the field observations were made by Marmer and his colleagues, whose sagacity is widely acknowledged.

VII. SPECIFICATIONS OF THE MODEL TESTS

The construction and verification of the Barataria Bay model discussed up to this point was of a routine nature and followed established precedents in most respects. The principal purpose of the model was to reconstruct the probable distribution of the maximum quantity of bleed water discharged at any time during the sulphur mining operations of the Freeport Sulphur Company. Toward this end apparatus was constructed which would discharge these maximum specified volumes as traceable material into the model at specified points under continuous discharge conditions. In each case the aim of the experiment was to determine the steady state distribution of the tracer under each of several wind conditions and at each of two dilution figures, namely 1 part in 200 and 1 part in 1000. The specifications for these discharge conditions were supplied by the Freeport Sulphur Company and are as follows:

Test A. Investigate the progress and distribution in the model of fresh water draining through the Barataria Bay estuary from the watershed to the north of Barataria Bay.

Test B. Investigate the distribution in the model of a tracer having theoretical kinematic similitude with specified bleed water and capable of showing dilution by the ambient water not in nominal excess of 1 part in 200 and 1 part in 1000 discharged at the points and at the rates given below:

at point VI, 1.4 million gallons per 24 hours, specific gravity 1.057[8] at 60°F,

at point VIII, 1.0 million gallons per 24 hours, specific gravity 1.024[8] at 60°F.

Test C. Duplicate Test B with the following additions:

Investigate the distribution in the model of a tracer having theoretical kinematic similitude with specified bleed water and capable of showing dilution by the ambient water not in nominal excess of 1 part in 200 and 1 part in 1000 discharged at the point and rate given below:

at the head of the Freeport Sulphur Company dilution canal, 1.5 million gallons of bleed water per 24 hours, specific gravity 1.055[8] at 60°F,

add at the same point 40 million gallons of Lake Grande Ecaille water per 24 hours, specific gravity 1.012[8] at 60°F drawn in the model from the geometrically similar point at which this dilution water is drawn into the pumps in the prototype.

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[8] See discussion beginning at the bottom of page 39.

VIII. CHEMISTRY OF THE BLEED WATER TRACER

In order to meet the specified conditions of the model tests the bleed water was simulated by sulphuric acid of suitable strength and specific gravity and the ambient water by ordinary tap water to which was added a suitable quantity of sodium carbonate and a fraction of a gram of brom cresol green indicator per model volume of about 600 liters. This choice of solutions was made in order to reduce as much as possible any chemical reaction between the solutions and the gypsum (calcium sulphate) plaster of which the model was made and also to avoid alteration of pH of the ambient water through acidification by atmospheric carbon dioxide.

Sulphuric acid introduced to simulate the discharge of bleed water at the specified points and rates in the model necessarily produced a yellow color change in the brom cresol green indicator in solution with it. The color of brom cresol green in alkaline solution is a pleasant blue and the color change as the pH rises through the range 4.0 to 5.6 is at first green and then bright yellow. The change is abrupt from blue to green and more gradual from green to yellow. As the sulphuric acid flowed with the circulation of the model a certain amount of mixing took place which diluted the sulphuric acid, and at the same time reaction took place with the carbonate ions present in the admixed ambient water. The mixing processes were mainly due to molecular diffusion and microturbulent exchange across the interface between

the sulphuric acid solution and the ambient water. Thus there was a steep gradient of pH through this boundary and the color change of the indicator with pH was at first too abrupt for the individual stages of color to be discerned. As time passed and distance from the source increased the gradient between the acid and ambient alkali usually weakened sufficiently for the individual color changes to be observed. At length when the acid concentration was no longer sufficient to maintain a pH greater than 4.0 the acid became invisible, or neutralized. As pointed out earlier, mixing processes in the model were insufficient to represent the rate of mixing known from field evidence to exist in the prototype, and, since only mixing would permit the process of chemical neutralization to take place, the acid color of the bleed water tracer was generally maintained too long and too far from the source.

Generally speaking the concentration of a sulphuric acid and a sodium carbonate solution can be adjusted so that the intermediate color change from greenish yellow to green will take place when one volume of the acid is thoroughly mixed with any specified number of volumes of carbonate solution. One gram molecular weight of dilute sulphuric acid will be neutralized by one gram molecular weight of sodium carbonate in aqueous solution. Thus if a day's discharge of bleed water is represented by the discharge of a certain volume of liquid containing 0.01 gram molecular weight of sulphuric acid, the presence of this acid will be

detectable through the yellow or green color of the brom cresol green indicator present until the acid has had an opportunity to mix and react with a volume of ambient water containing 0.01 gram molecular weight of sodium carbonate. If the volume of 0.01 gram molecular weight of sulphuric acid solution is 1/1000 as great as the volume of ambient water containing 0.01 gram molecular weight of sodium carbonate solution, the boundary across which the acid ceases to be visible represents a dilution of the acid by a factor of 1000. Thus the color of the acid discharge was characteristic of pH lower than 4.0 and concentrations greater than 1 part in 1000, and invisible if its dilution exceeded this predetermined value. The same reasoning applies to the 1 part in 200 dilution contour. During operation of the model, samples of the solutions concerned in the bleed water tracer system were titrated repeatedly to end points in both the green and yellow ranges. These values represented the greatest and least measurable dilutions respectively of the acid component and served to define numerically the dilution contours represented by color changes in the model.

The chemical titrations of simulated bleed water against ambient water were referred to a standard sodium carbonate solution of approximately 0.2 normal strength. An intermediate standard sulphuric acid solution of approximately 0.01 normal strength was prepared in order to monitor the concentration of sodium carbonate in the ambient water. The simulated bleed water

solutions of sulphuric acid were made up in two liter quantities to a strength of approximately 0.5 normal for the 1 part in 1000 tests and approximately 0.1 normal for the 1 part in 200 tests. The exact normality of each solution was determined through comparison with the standard sodium carbonate solution. The standard sodium carbonate solution in turn was titrated against the intermediate standard acid solution. It was found that the acid prepared for the 1 part in 200 tests was 9.94 times as concentrated as the intermediate standard acid and that the acid prepared for the 1 part in 1000 tests was 50.2 times as concentrated as the intermediate standard acid. The entire mass of ambient water in the model was rendered suitably alkaline by addition of sodium carbonate. It was found that approximately 2.0 milliliters of the intermediate standard acid solution produced the blue-green to blue change of color in the brom cresol green indicator and that approximately 3.1 milliliters of intermediate standard acid produced the green-yellow color change when added to 50 milliliters of the sodium carbonate solution used as the ambient water. This ratio of concentrations was monitored by titrations throughout the model tests. During each test the dilution factor inevitably tended to shift. The average dilution factor was calculated for each run and the results of these calculations are tabulated in the log sheets and entered on the smooth plots of the results for each test. Two values are given; the value for the yellow-green change representing the highest measurable concentration of simulated bleed

water, and the value for the green-blue change representing the lowest measurable concentration of simulated bleed water. In each case it was the intention to make these values straddle the nominal dilutions specified for the tests. The dilutions were calculated as follows:

V_g = volume of Gulf water titrated (50 cc by volumetric pipette)

V_a = volume of intermediate standard acid used to neutralize V_g

V_b = volume of simulated bleed water equivalent to V_g

for 1:200 tests
$$\frac{V_g}{V_b} = 9.96 \times \frac{V_a}{V_b} ; \qquad (6)$$

for 1:1000 tests
$$\frac{V_g}{V_b} = 50.2 \times \frac{V_a}{V_b} \qquad (7)$$

IX. AUXILIARY PUMPING SYSTEMS

The scaled quantities of bleed water were pumped through 1/8-inch copper tubes embedded in the plaster monolith. These tubes were terminated at point VI on the north bank of Humble Canal, point VIII on the west bank of the dredge cut, at the head of the dilution canal and on the shore of Lake Grande Ecaille adjacent to the head of the dilution canal (see fig. 14). The first three tubes were attached to a positive displacement pump driven by an electric motor through suitable screw. The fourth tube was used to withdraw the dilution volumes from Lake Grande Ecaille for return at the head of the dilution canal together with the appropriate volumes of simulated bleed water. Thus the hydraulic activities of the Freeport Sulphur Company mining operations having significance in these tests were substantially reproduced in the model.

The kinematic scaling factor of discharge Q_r being $1/5.3 \times 10^7$ per mean solar day, the discharge per mean solar minute into the model is $Q_m = Q_p T_r$ or $1/7.68 \times 10^{10}$. One million gallons in the prototype is therefore represented in the model by a volume of 0.05 cubic centimeter of liquid or approximately one drop. Pumps that will deliver such small quantities of liquid per minute are difficult to build and to operate. In order to increase the volumes to be discharged by a single pumping unit, and to simplify the maintenance of predetermined differences of

specific gravity, which in this case were more significant than specific gravity ratios, permission was obtained to average the specified specific gravities of the simulated bleed waters and to maintain this average difference above that of the ambient water of specific gravity 1.000 at 60°F rather than 1.012. Since specific gravity is more easily measured than density and is numerically equivalent to density if comparisons are made at a convenient standard temperature, usually 60°F or 20°C, the resulting error in the equivalent density ratio was 1.2%. The average difference in specific gravity of the simulated bleed water and ambient water at 60°F was taken as 1.045 - 1.012 = 1.033 corresponding closely to that of a 5% NaCl solution at the same temperature. Thus the kinematic density difference 0.033 gm/cc, measured in terms of specific gravity under homogeneous temperature conditions equivalent to 60°F, was adjusted by adding the necessary quantities of Na_2SO_4 to the bleed water tracer.

A positive displacement pump had been designed and built to handle the sum of both the simulated bleed water volumes and the dilution volumes, but later it was thought better practice to actually withdraw the dilution volumes from the model since these volumes form a small but possibly significant part of the local circulation. Relieved of this relatively major burden the bleed water pump had to be run at very slow speeds, and during Test B it was found that accurate proportional delivery of the scaled volumes could not be detected and controlled quickly enough to

correct the "day-by-day" discharge rates but that the total discharge over a period of a "week" was acceptable. Since the points of discharge in Test B are so close together and united in a common portion of the detailed circulation no significant error in the equilibrium distribution of bleed water could occur as a result of small proportioning errors. In Test C, however, a small proportioning error would be highly significant in the equilibrium distribution of bleed water because the dilution canal is part of a circulation pattern that is distinct from the Humble Canal system. Test C was, therefore, not run until a reliable rotary proportioning device had been built and installed. The total discharge of the bleed water pump was monitored as before by timing the revolutions of the driving motor shaft and screw. The results obtained in all bleed water discharge tests are believed to be representative and consistent in spite of the difficulties enumerated.

Two other pumping systems had significance in the model tests (1) the dilution system which withdrew scaled volumes of water from Lake Grande Ecaille and discharged them as a mixture with properly scaled volumes of bleed water added, and (2) the rainfall pumping system. The bleed water dilution system consisted of a small gear pump driven by a separate electric motor and monitored by counting the number of drops discharged per minute as they fell from a calibrated dropper tip. Since the scaled volumes involved a drop every few seconds it was possible to observe the rate of

discharge quite readily and maintain acceptable accuracy. Similarly the rain water circulation system involved the discharge of 165 cubic centimeters per minute, a volume equivalent to Marmer's estimate of the average fresh water drainage (450×10^6 ft.^{3}/day) into Barataria Bay. This volume was pumped from the Gulf portion and was piped around the outside of the model to the Little Lake equivalent box where it discharged as a small steady stream. This flow was adjusted by means of a needle valve at the pump. The same pump also circulated a continuous stream in the Gulf of Mexico portion of the model through a venturi tube which entrained the Gulf water and produced the characteristic westward trend of the circulation of Gulf past the mouths of the passes into the Barataria Bay estuary. The venturi system was adjusted to produce a steady westward current of 0.25 "knot" along the coast line.

X. THE RELIABILITY OF THE MODEL TESTS

The final figure of merit for all the observations represented in the model tests can be estimated only very roughly. The model itself is rated at 7 on a scale of 10. The equilibrium distribution of bleed water in the model is estimated at the same figure. Hence the reliability of the bleed water tracer tests must be about 5 on a scale of 10. This figure of merit should be interpreted to mean that the contours of bleed water distribution may be overextended with respect to the actual occurrence in the prototype by a factor of 2 or they may be underextended by a factor of 1/2. The kinematic density scale chosen in connection with simulated bleed water discharge caused the bleed water to sink unnaturally and inhibit the mixing processes that would otherwise dilute the discharge. With the condition of insufficient mixing applying so heavily to the first possibility and to the estimate of the figure of merit itself, underextension of the dilution contours of bleed water distribution is improbable.

XI. "FIRST ARRIVAL" TESTS

In addition to the tests for the equilibrium distribution of bleed water and penetration of fresh water discharge some separate tests were run and photographed to determine the minimum time required for a parcel of water composed of an hour's discharge from point VI in Humble Canal to travel to the head of Bay Ronquille. It was found that the volume of colored ink tracer released at point VI had to be deposited at a very critical moment near the beginning of a tropical ebb tide in order to reach the head of Bay Ronquille before the following flood carried it back toward its starting point. The minimum time required for a parcel to actually reach the head of Bay was approximately seven or eight hours.

Experiments in the field show that the travel time on the tropical flood tide from point VI in Humble Canal to Fisherman's cut on the east side of the Freeport Sulphur Company dredge cut is about five hours. The model confirms this result provided the tracer has neutral density. If the tracer is of kinematically (1/1) scaled density the discharge through Fisherman's cut is delayed until the dredge cut basin is filled and a stratified layer established which is almost level with the threshold of Billet Bay. Following this the travel time is the same for solutions of both neutral and kinematic density.

Appendix I - Schedule of procedure in model tests.

Preliminary readiness check

1. check titre of ambient water and sea level, clean water surface
2. check specific gravities of ambient water and simulated bleed water for difference of 0.033
3. check rate of fresh water discharge at 165 cc/min.
4. check filling of bleed water pumps with proper acid solution
5. check rate of discharge of bleed water pump
6. blow out bleed water discharge lines and flush with ambient water
7. fill bleed water discharge lines with proper acid solution to point of incipient discharge
8. check rate of going of tide machine
9. check tide recorder for ink and paper supply
10. check wind sock
11. check run code number
12. replace all photofloods and test lighting system, measure illumination
13. check power to wind machines, and alignments
14. check film supplies, cameras and exposures
15. check velocity of flow through Barataria Pass, Bayou St. Denis

Operating duties

Chemist

1. keep running check and log of titre of ambient water
2. operate wind machines on signal
3. place and remove wind sock on signal
4. change code numbers on signal
5. replace photoflood lamps as necessary

Mechanist

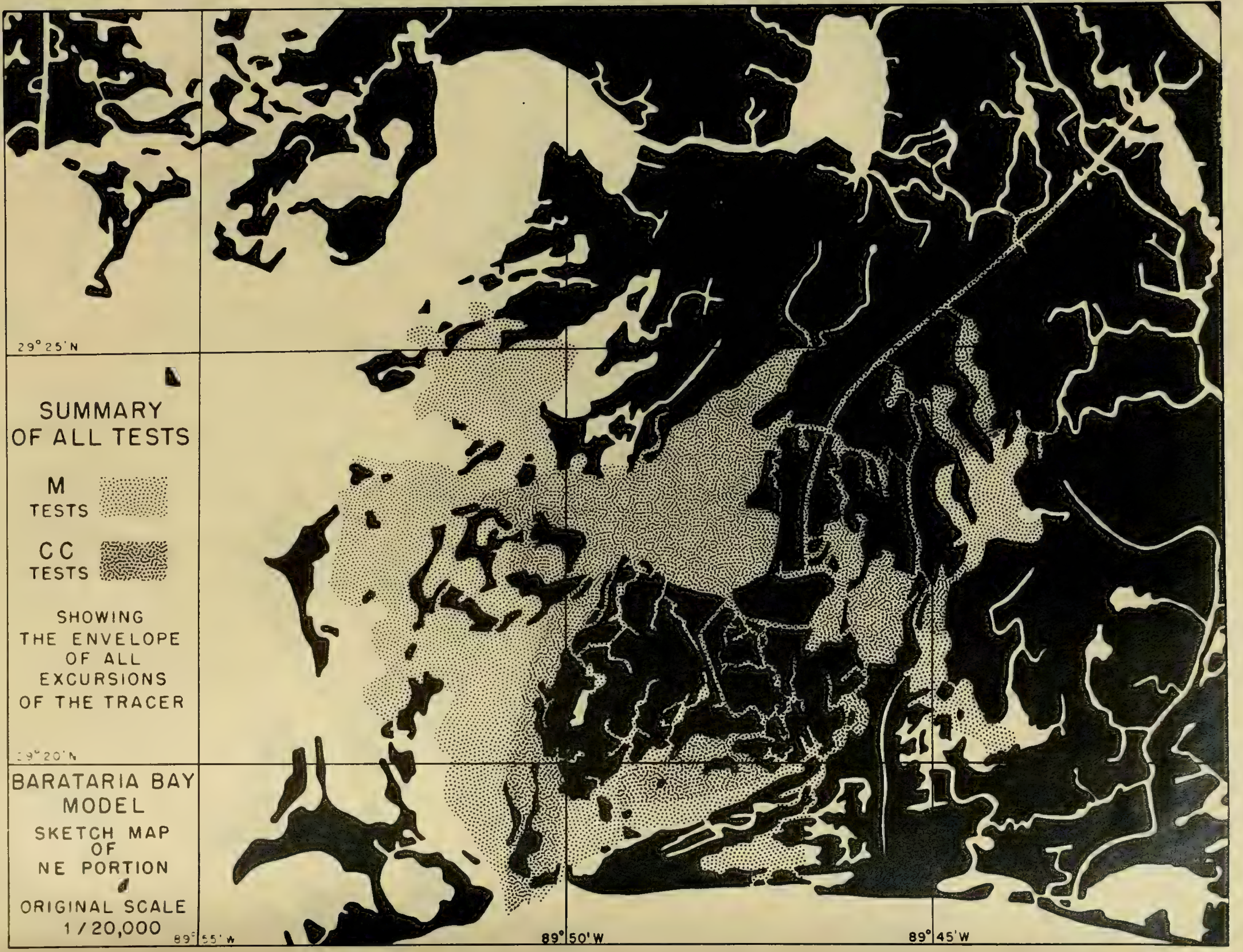
1. keep continuous watch on bleed water discharge rate, dilution pump rate, tide machine rate and fresh water discharge
2. start and stop and label tide recorder on signal
3. start and set elapsed-time clock on signal
4. replace photoflood lamps as necessary

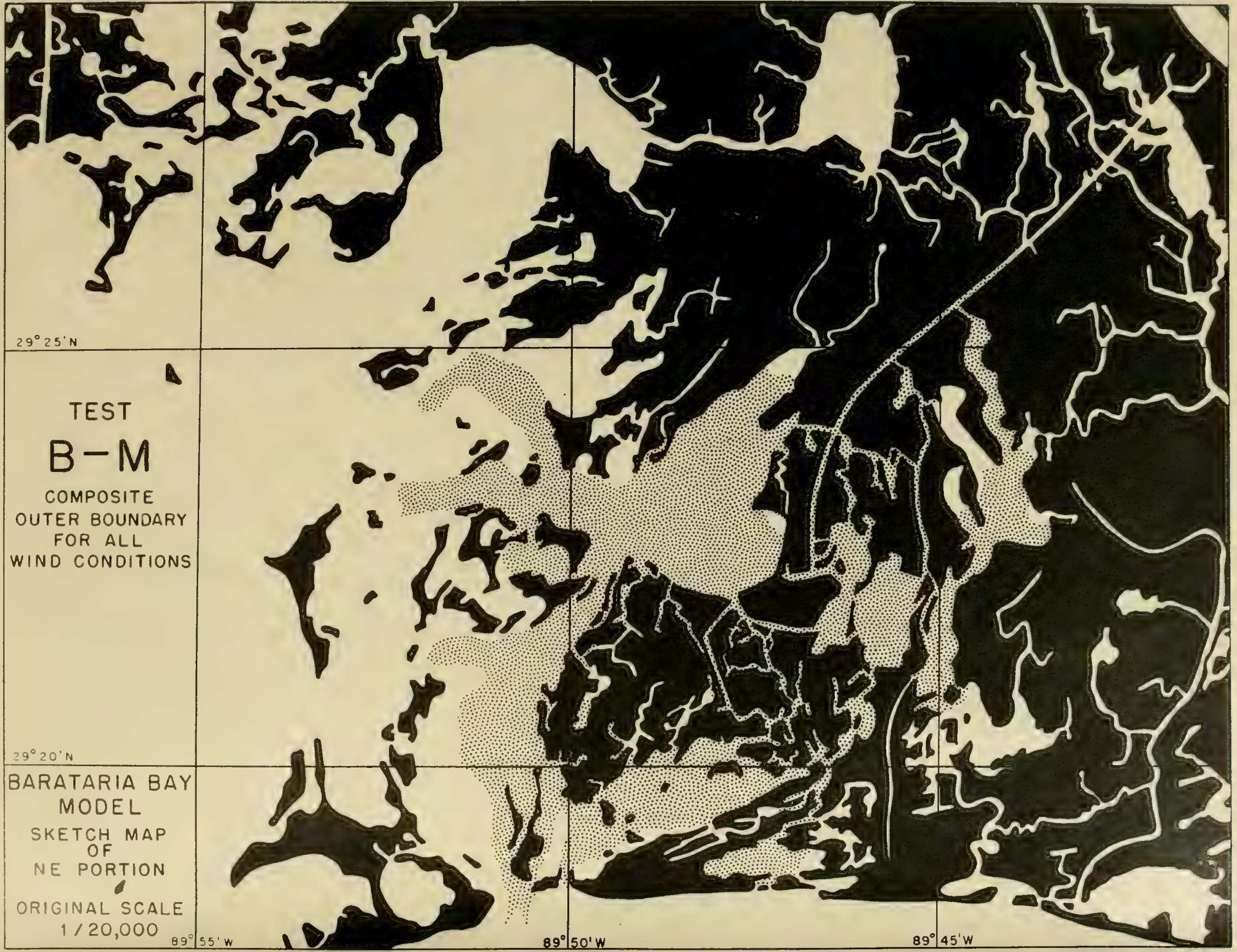
Photographer

1. keep continuous watch on framing, exposure, focus and film supply of all cameras, change film as required
2. keep watch on the over-all behavior of the model
3. general instructions for operating 16 mm time-lapse and 35 mm Graflex cameras
    a. operate 16 mm time-lapse Bolex with 15 mm Eastman Cine f-2.7 objective and Type A Kodachrome in 100 foot rolls at the rate of 1 frame per second
    b. operate 35 mm Graflex Photorecord camera with 44 mm Wollensak f-3.2 objective at air pressure of 22 lbs using 100 foot rolls Type A Kodachrome at the rate of 1 frame every 7.5 seconds. Synchronize with model clock
    c. operate 35 mm Leica with 127 mm Wollensak objective f-4.5 at optional intervals during runs to equilibrium and at intervals of approximately one week during wind tests. Include the vicinity immediately adjacent to Freeport Sulphur Company area in field of view. Try to record significant changes or developments of the bleed water patterns.
4. make serial photographic record of model tests as follows:
    a. run to equilibrium without wind - run both 16 and 35 mm cameras
    b. run to summer wind equilibrium - run both 16 and 35 mm cameras
    c. return to no-wind equilibrium - no photographs
    d. run to winter wind equilibrium - run both 16 and 35 mm cameras
    e. return to no-wind equilibrium - no photographs
    f. cardinal and intercardinal winds - start 16 and 35 mm cameras when equilibrium is attained, continue photographing until one-half monthly progression of tides has passed.
5. keep log of photographs and model behavior

Completion duties

1. secure all electrical machinery and lighting equipment
2. flush model free of distributed acid
3. dry off land areas with sponges
4. secure work lights


29° 25' N
SUMMARY OF ALL TESTS
M TESTS
CC TESTS
SHOWING THE ENVELOPE OF ALL EXCURSIONS OF THE TRACER
29° 20' N
BARATARIA BAY MODEL
SKETCH MAP OF NE PORTION
ORIGINAL SCALE 1/20,000
89° 55' W
89° 50' W
89° 45' W



TEST

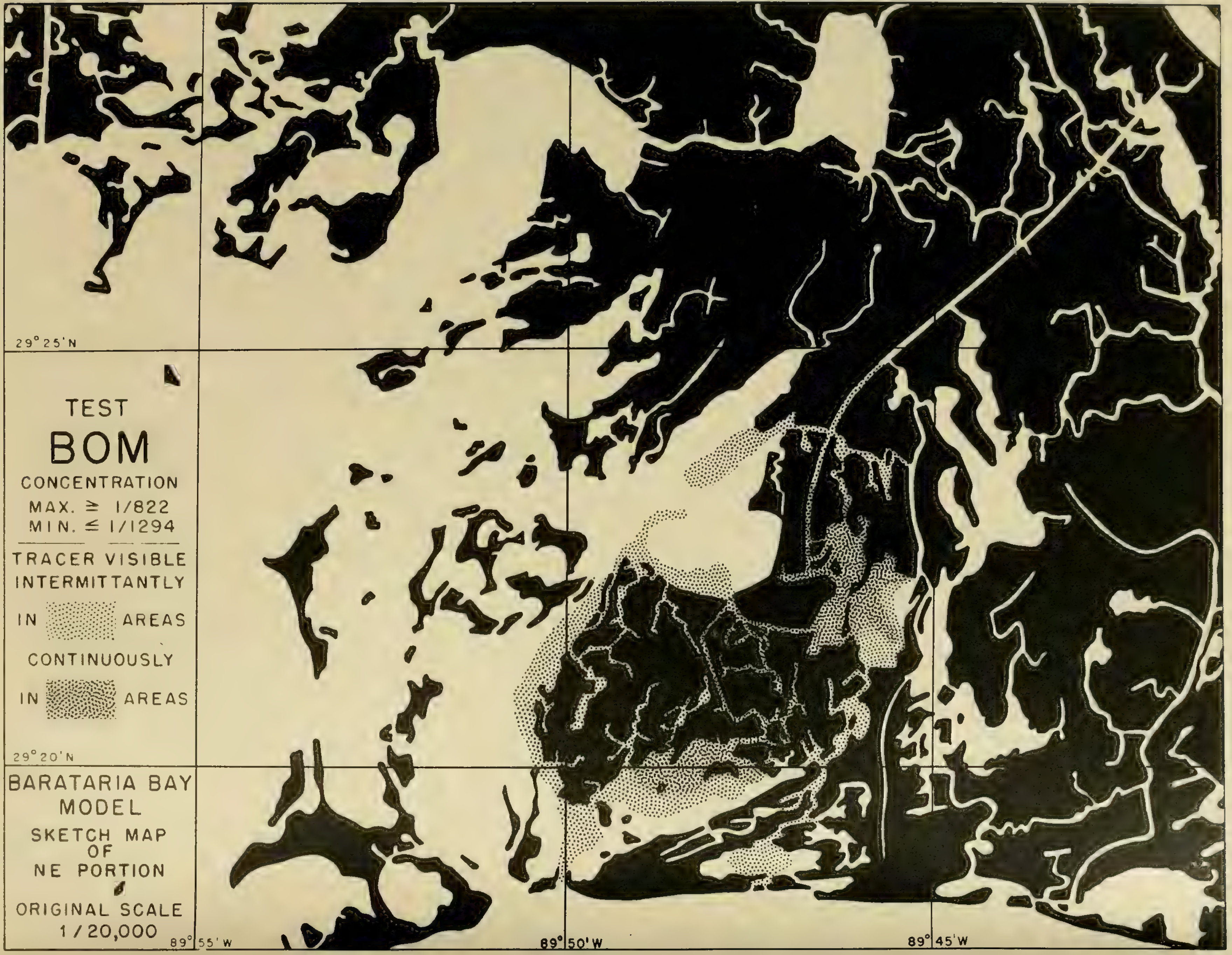
B—M

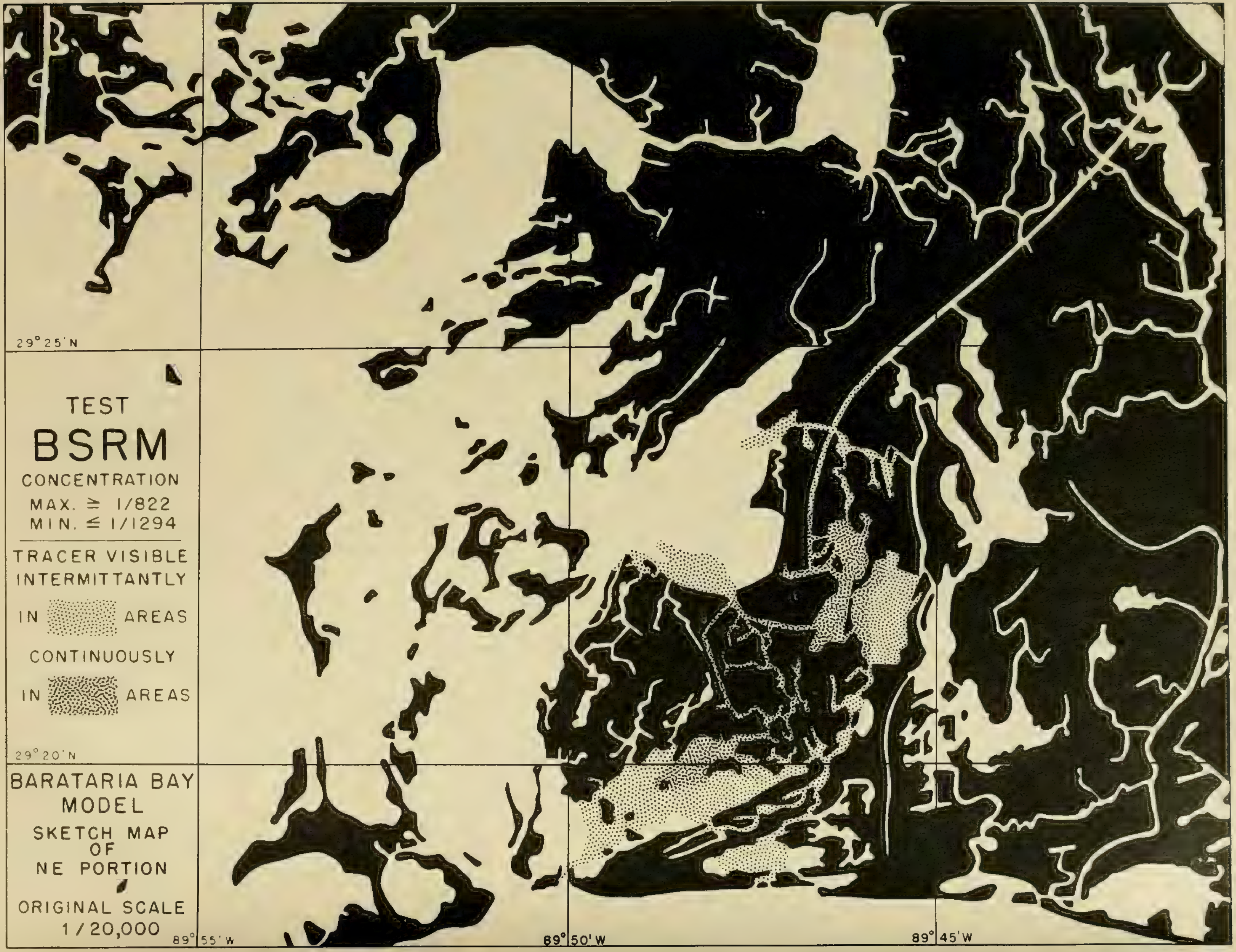
COMPOSITE
OUTER BOUNDARY
FOR ALL
WIND CONDITIONS

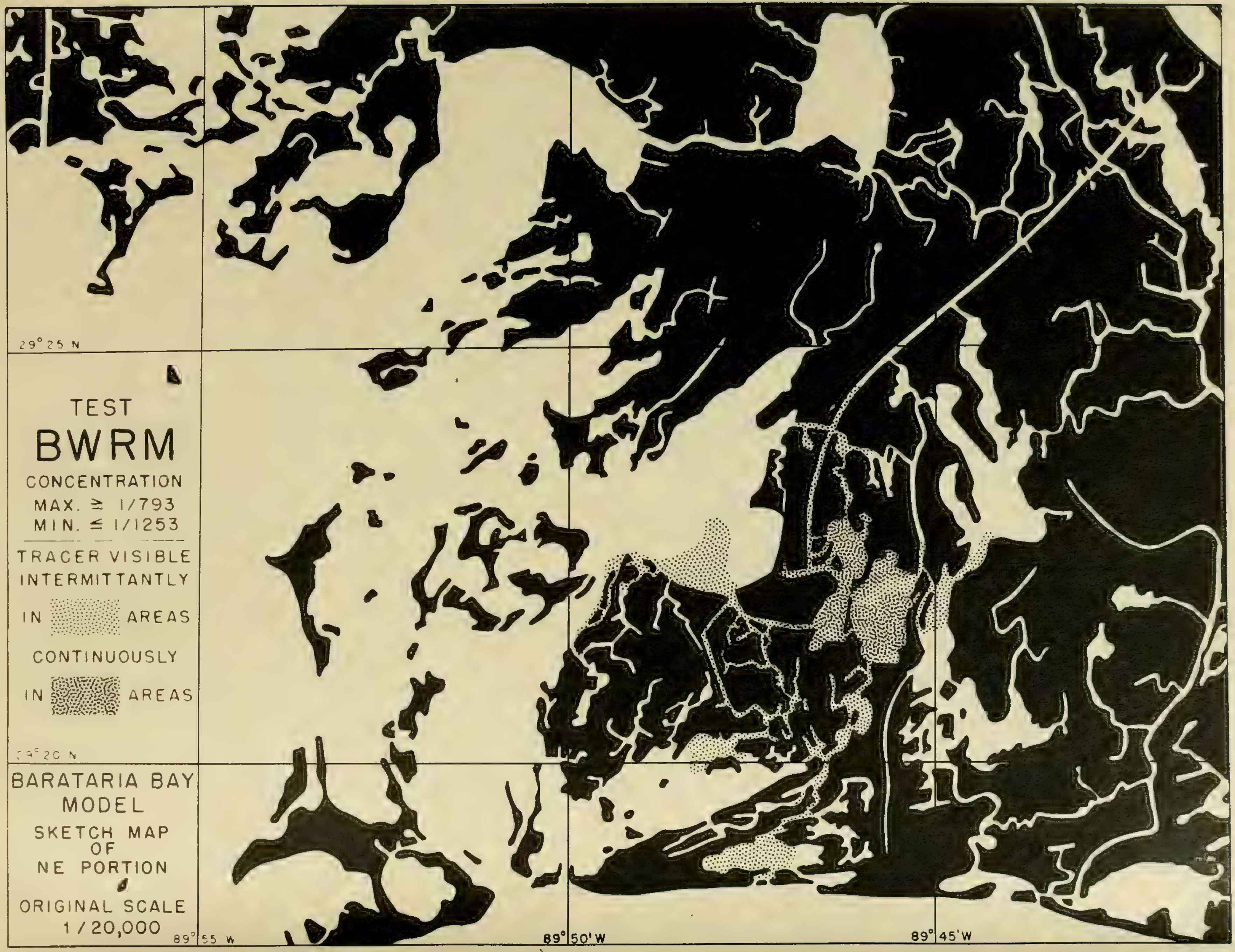
BARATARIA BAY
MODEL

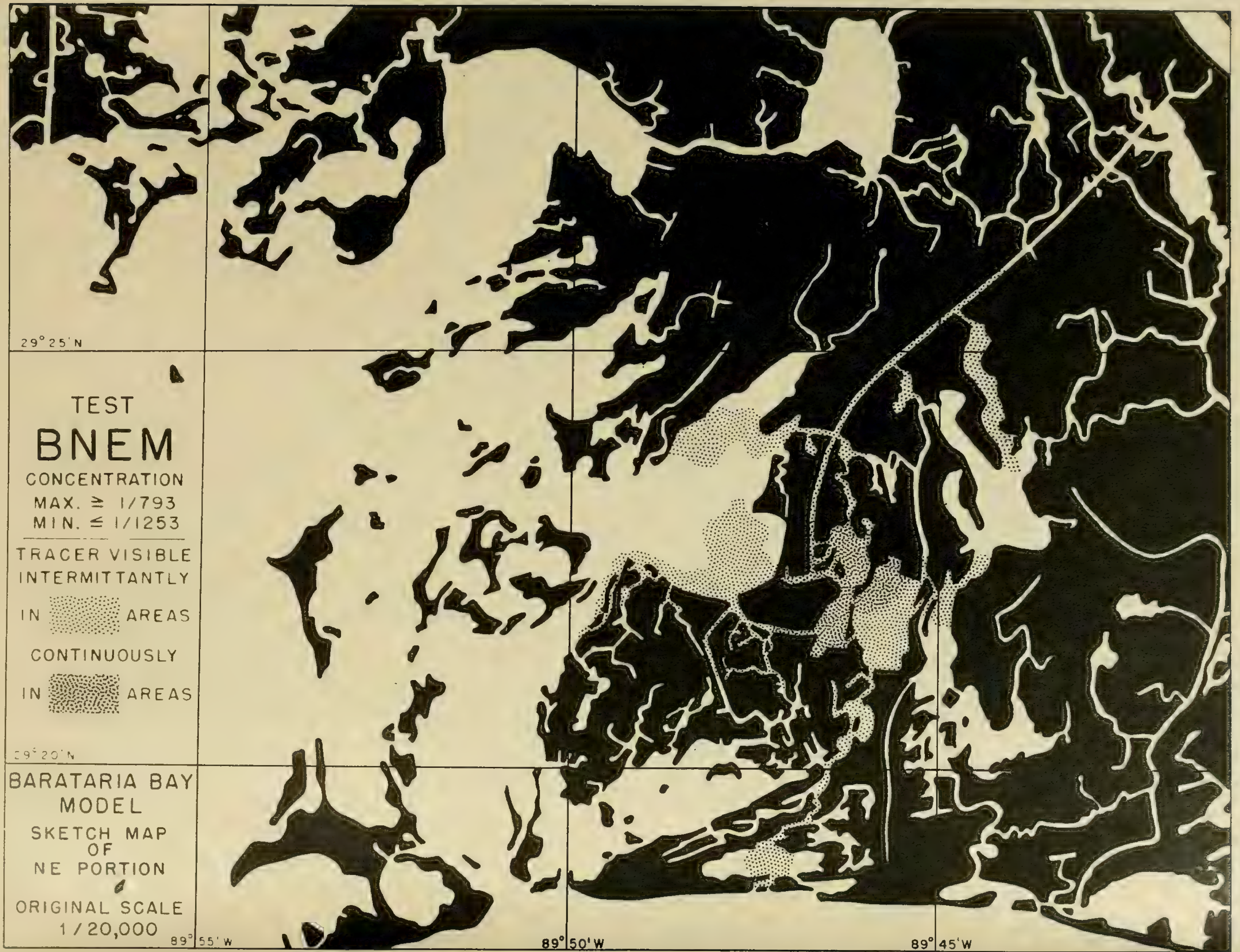
SKETCH MAP
OF
NE PORTION

ORIGINAL SCALE
1/20,000


TEST
BOM
CONCENTRATION
MAX. ≧ 1/822
MIN. ≦ 1/1294
TRACER VISIBLE
INTERMITTANTLY
IN ░ AREAS
CONTINUOUSLY
IN ▓ AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
29°25'N
29°20'N
89°55'W
89°50'W
89°45'W


29°25'N
TEST
BSRM
CONCENTRATION
MAX. ≥ 1/822
MIN. ≤ 1/1294
TRACER VISIBLE
INTERMITTANTLY
IN AREAS
CONTINUOUSLY
IN AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W


29° 25 N
TEST
BWRM
CONCENTRATION
MAX. ≥ 1/793
MIN. ≤ 1/1253
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
29° 20 N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89° 55 W
89° 50' W
89° 45' W



TEST

BNEM

CONCENTRATION

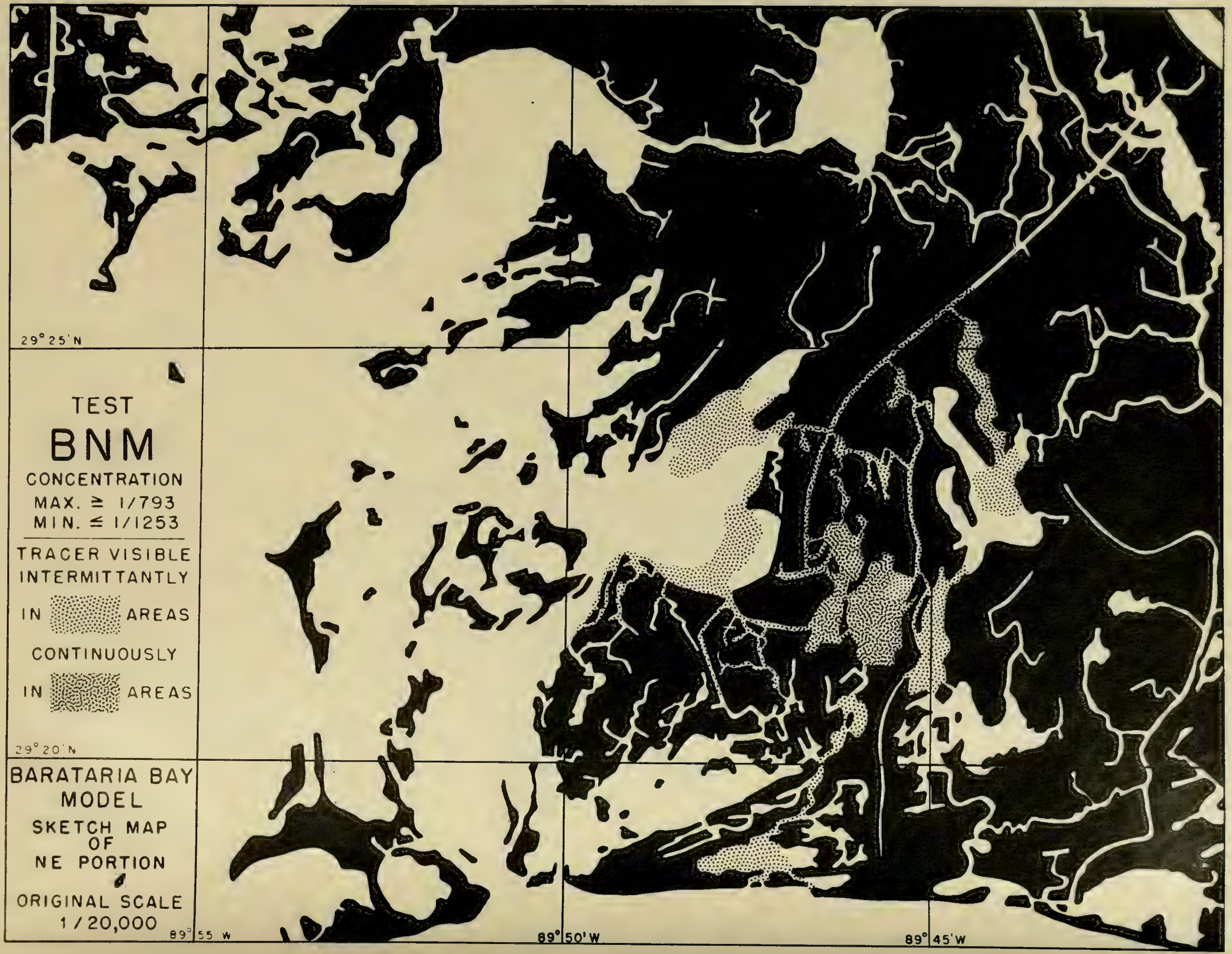
MAX. ≥ 1/793

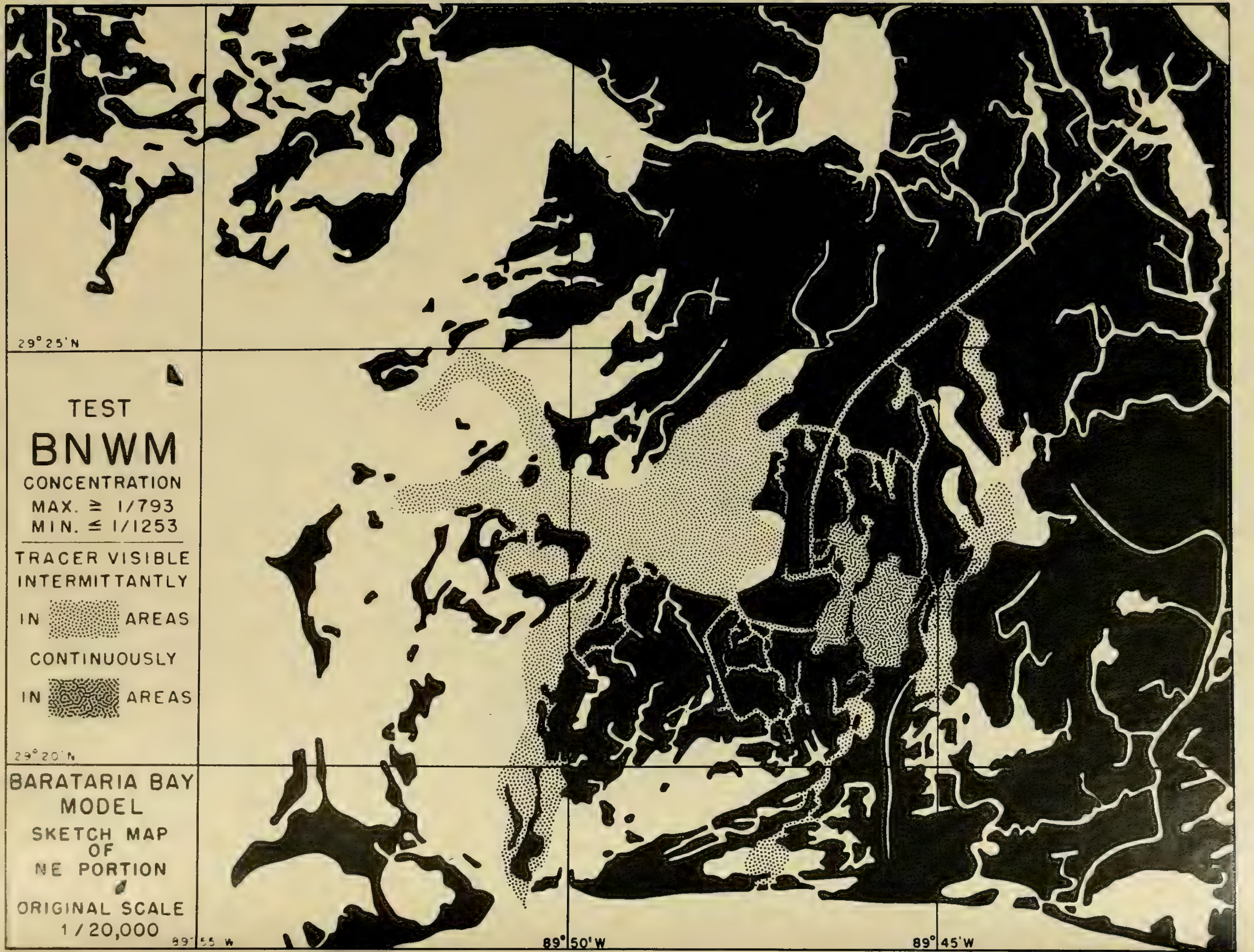
MIN. ≤ 1/1253

BARATARIA BAY MODEL

SKETCH MAP OF NE PORTION

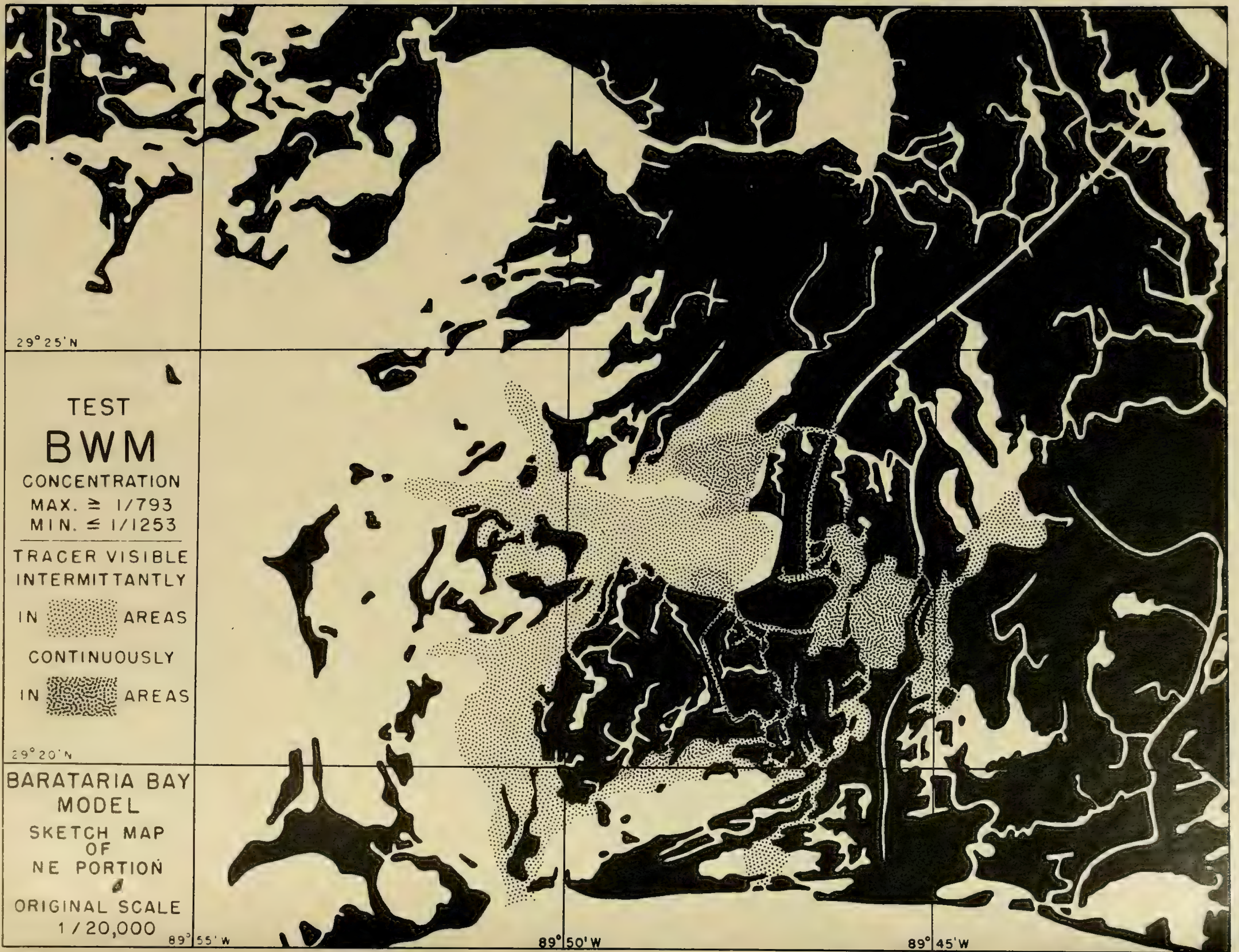
ORIGINAL SCALE 1/20,000

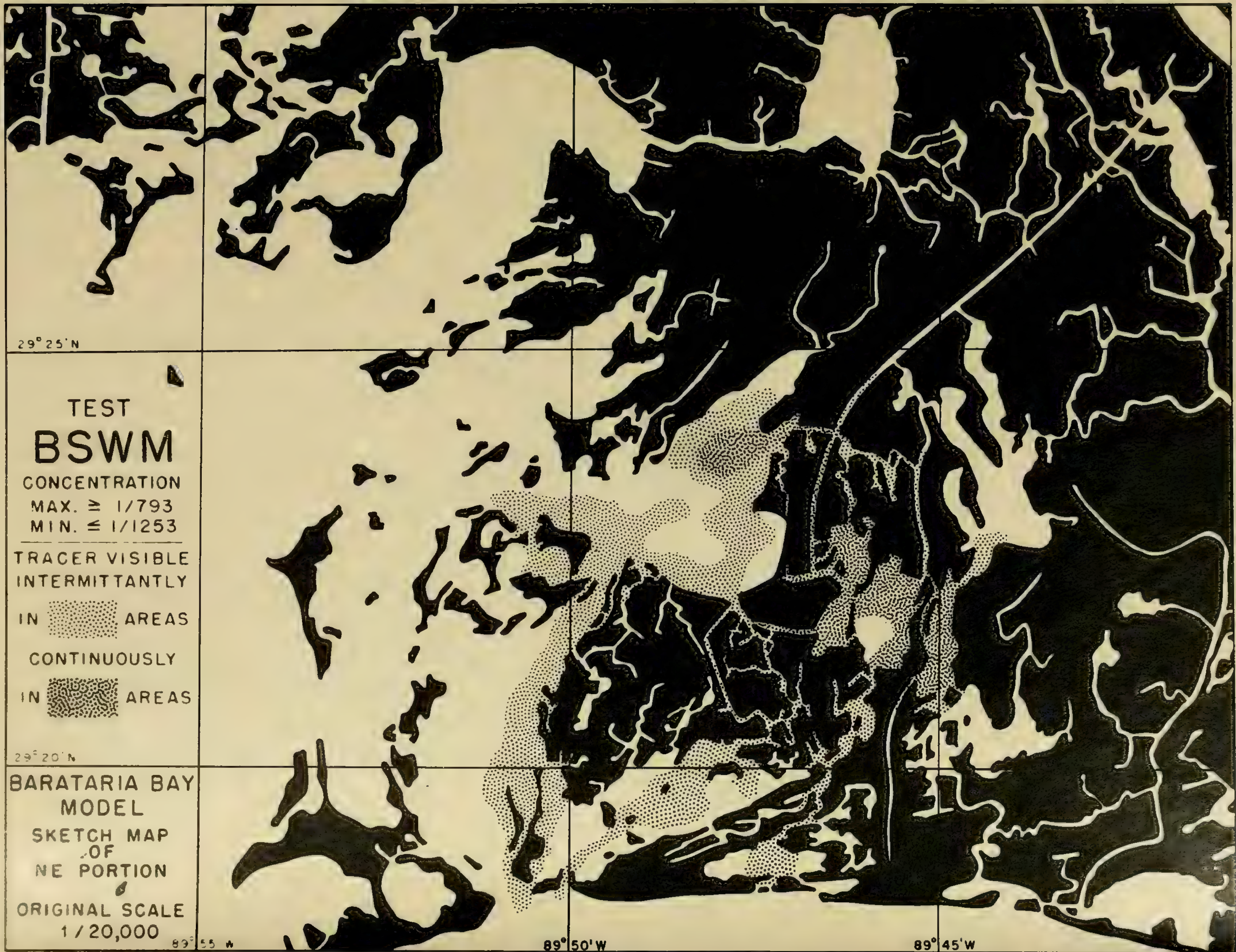

29° 25' N
TEST
BNM
CONCENTRATION
MAX. ≥ 1/793
MIN. ≤ 1/1253
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
29° 20' N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1 / 20,000
89° 55' W
89° 50' W
89° 45' W

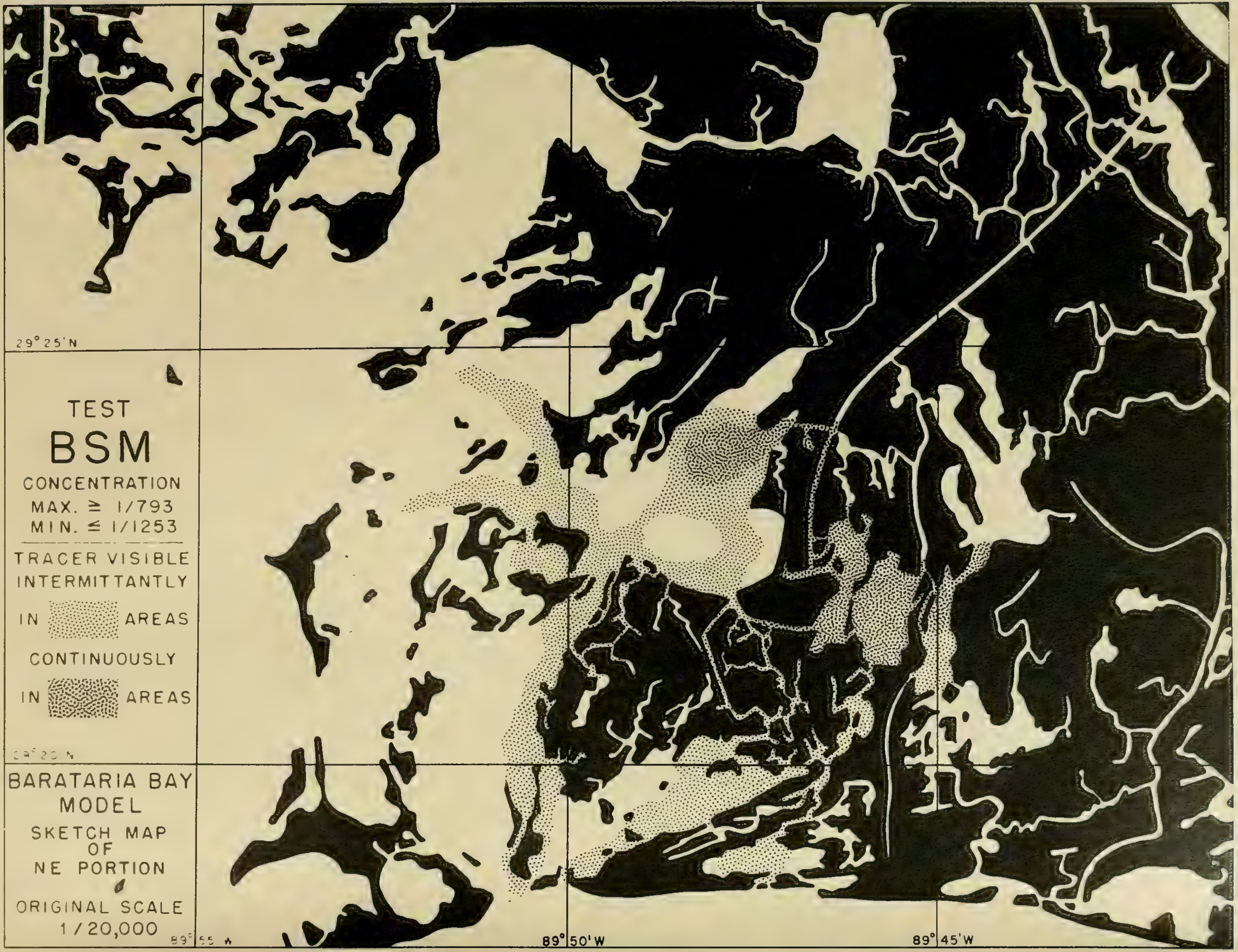


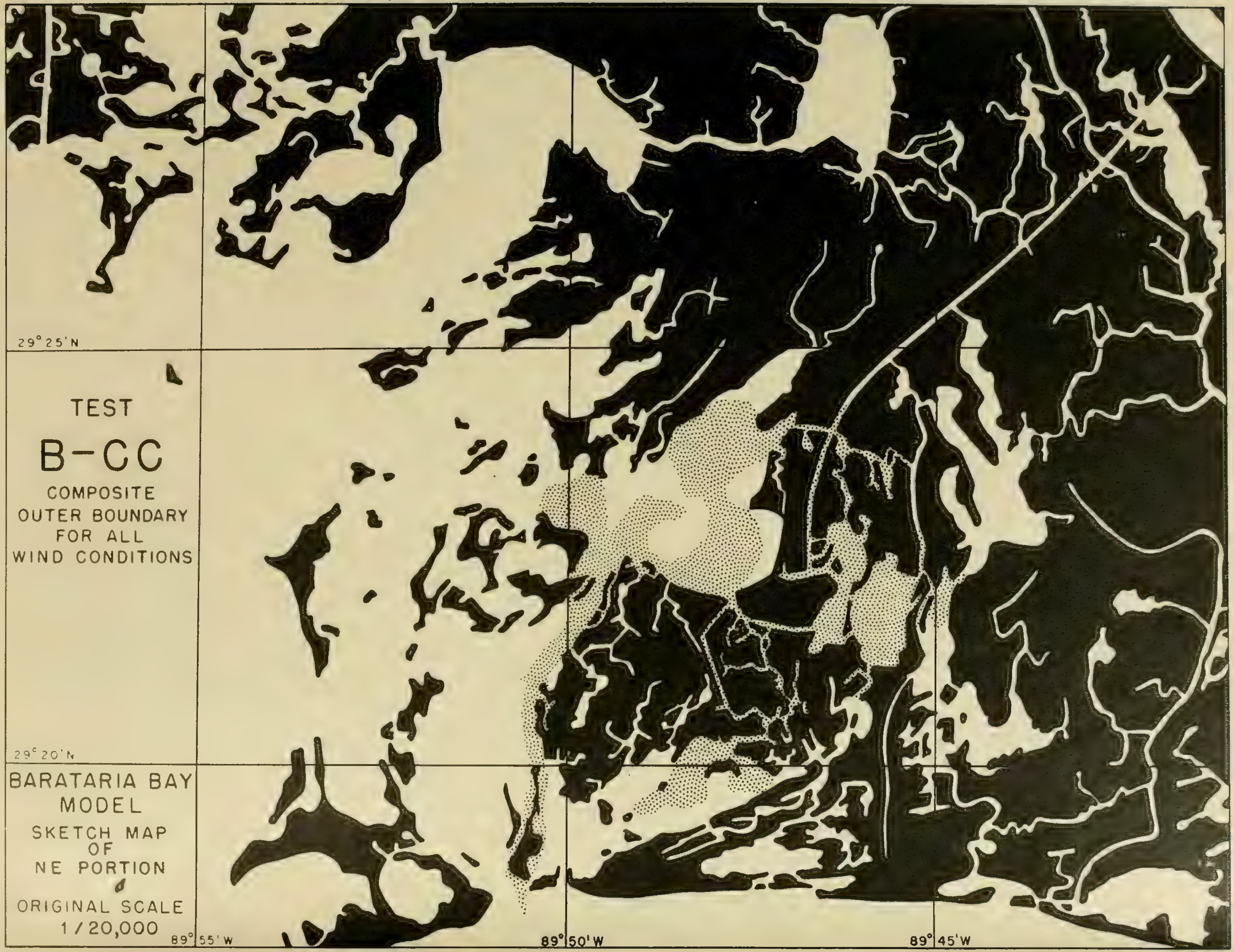
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION

ORIGINAL SCALE
1/20,000


TEST
BWM
CONCENTRATION
MAX. ≥ 1/793
MIN. ≤ 1/1253
TRACER VISIBLE
INTERMITTANTLY
IN AREAS
CONTINUOUSLY
IN AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1 / 20,000
29° 25' N
29° 20' N
89° 55' W
89° 50' W
89° 45' W


TEST
BSWM
CONCENTRATION
MAX. ≥ 1/793
MIN. ≤ 1/1253
TRACER VISIBLE
INTERMITTANTLY
IN ▒ AREAS
CONTINUOUSLY
IN ▓ AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
29°25'N
29°20'N
89°55'W
89°50'W
89°45'W


TEST
BSM
CONCENTRATION
MAX. ≥ 1/793
MIN. ≤ 1/1253
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▦ AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
29°25'N
29°20'N
89°55'W
89°50'W
89°45'W



TEST

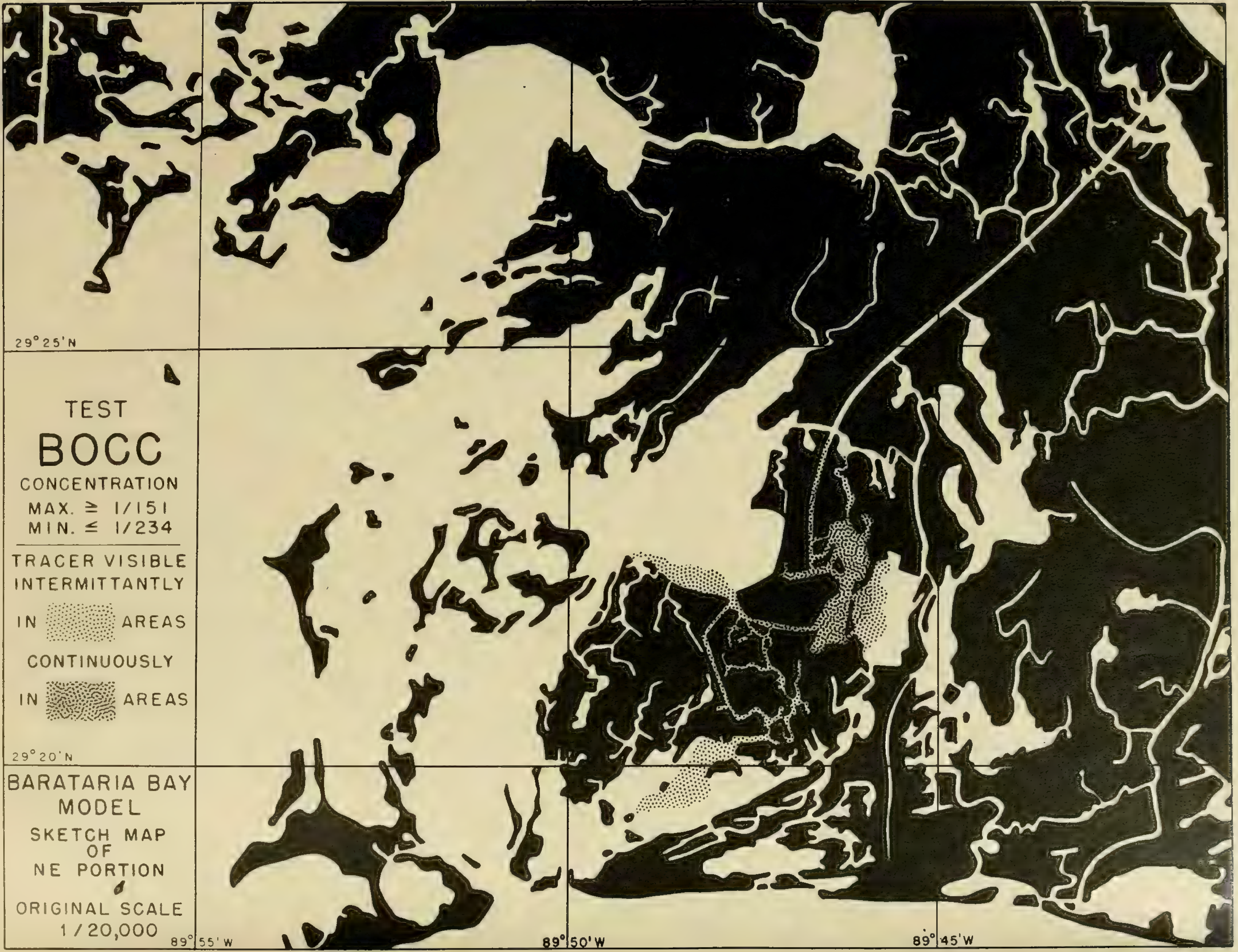
B-CC

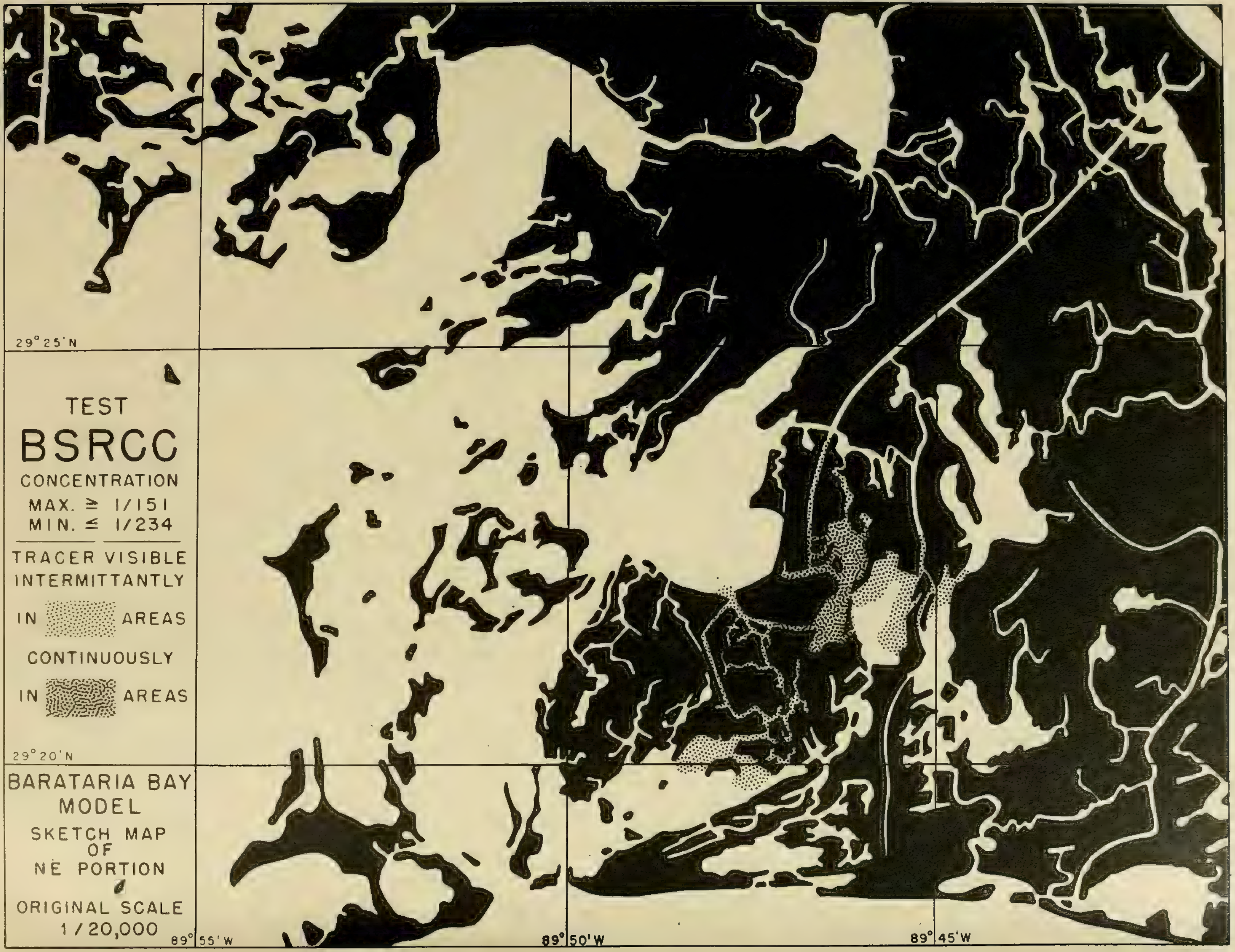
COMPOSITE
OUTER BOUNDARY
FOR ALL
WIND CONDITIONS

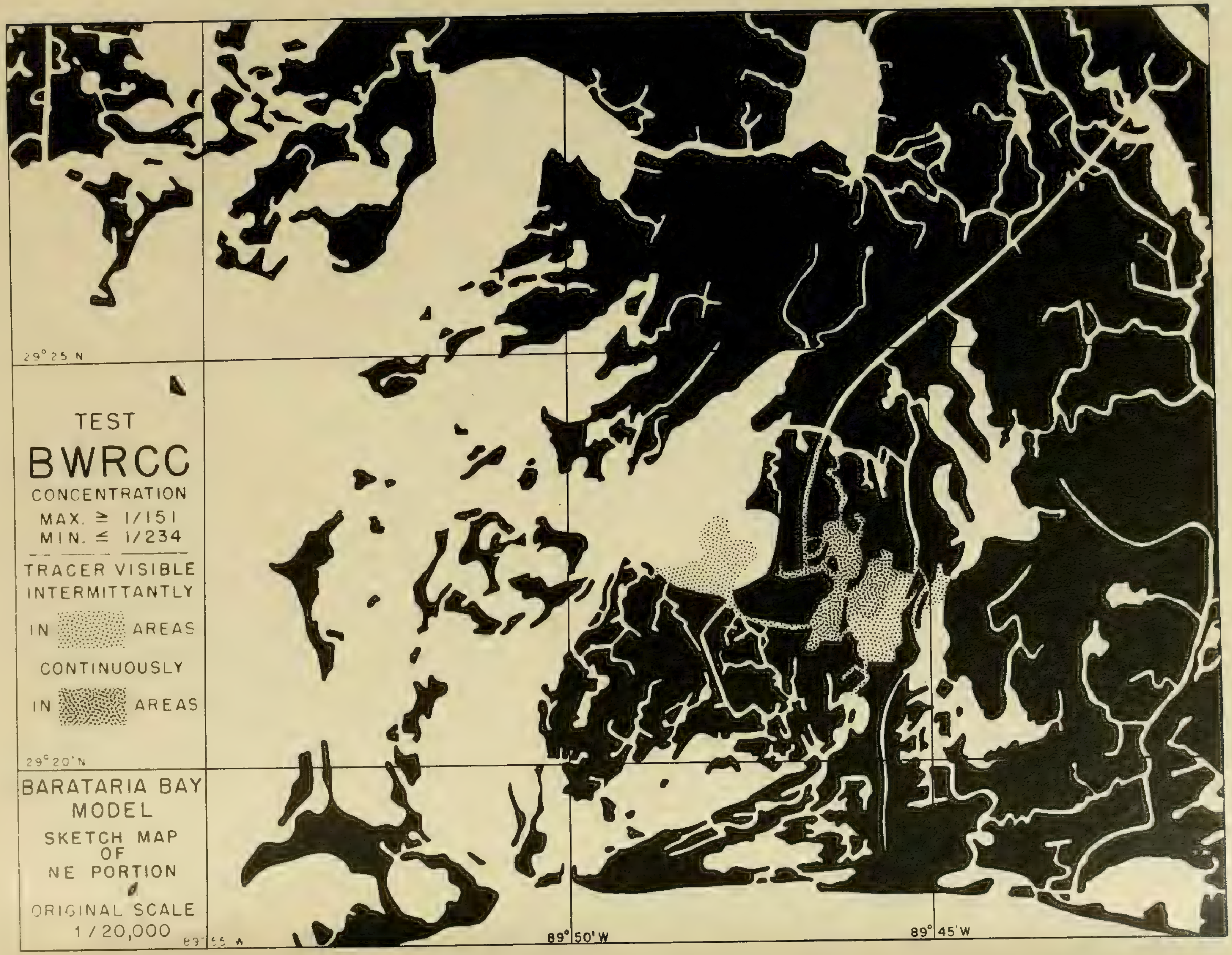
BARATARIA BAY
MODEL

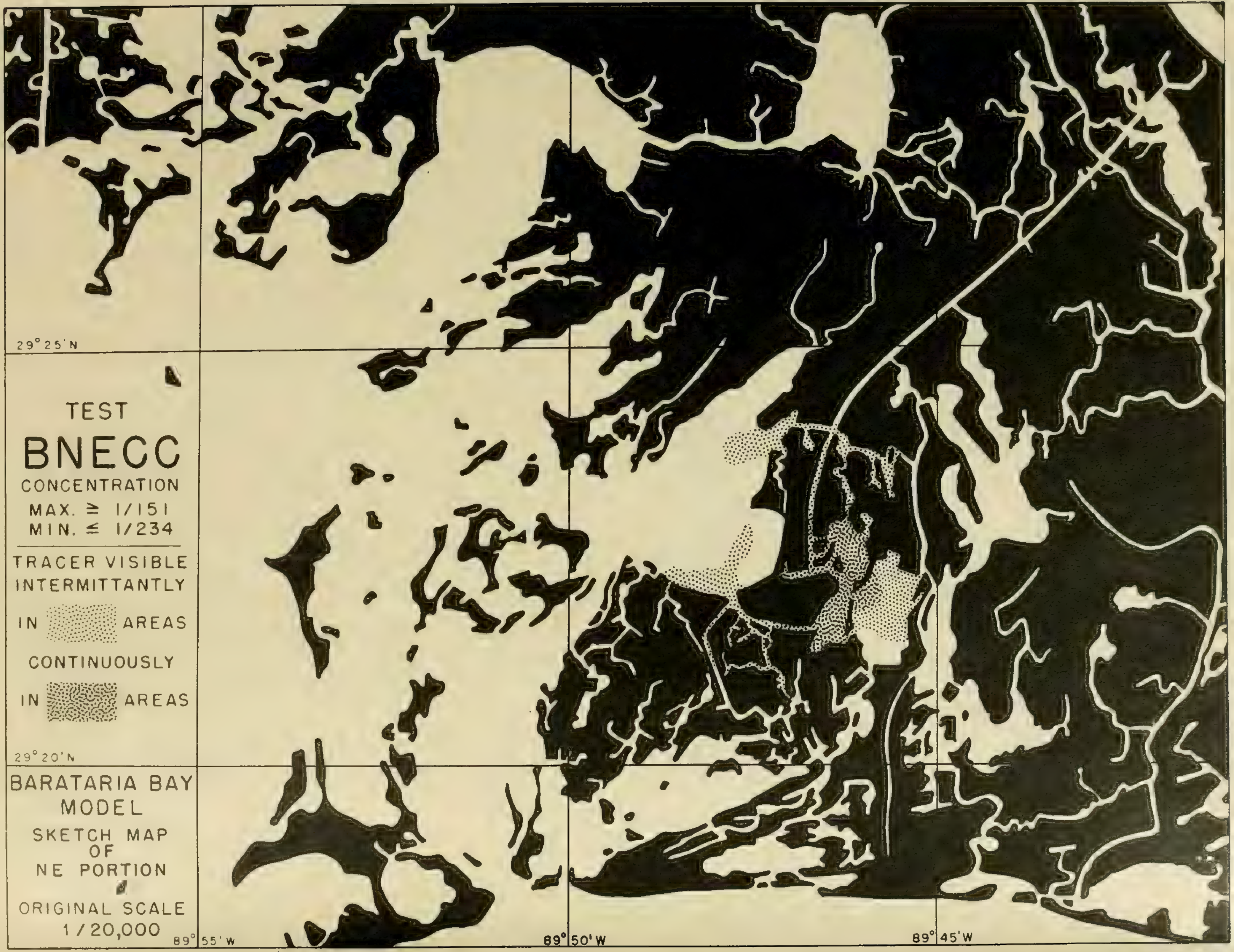
SKETCH MAP
OF
NE PORTION

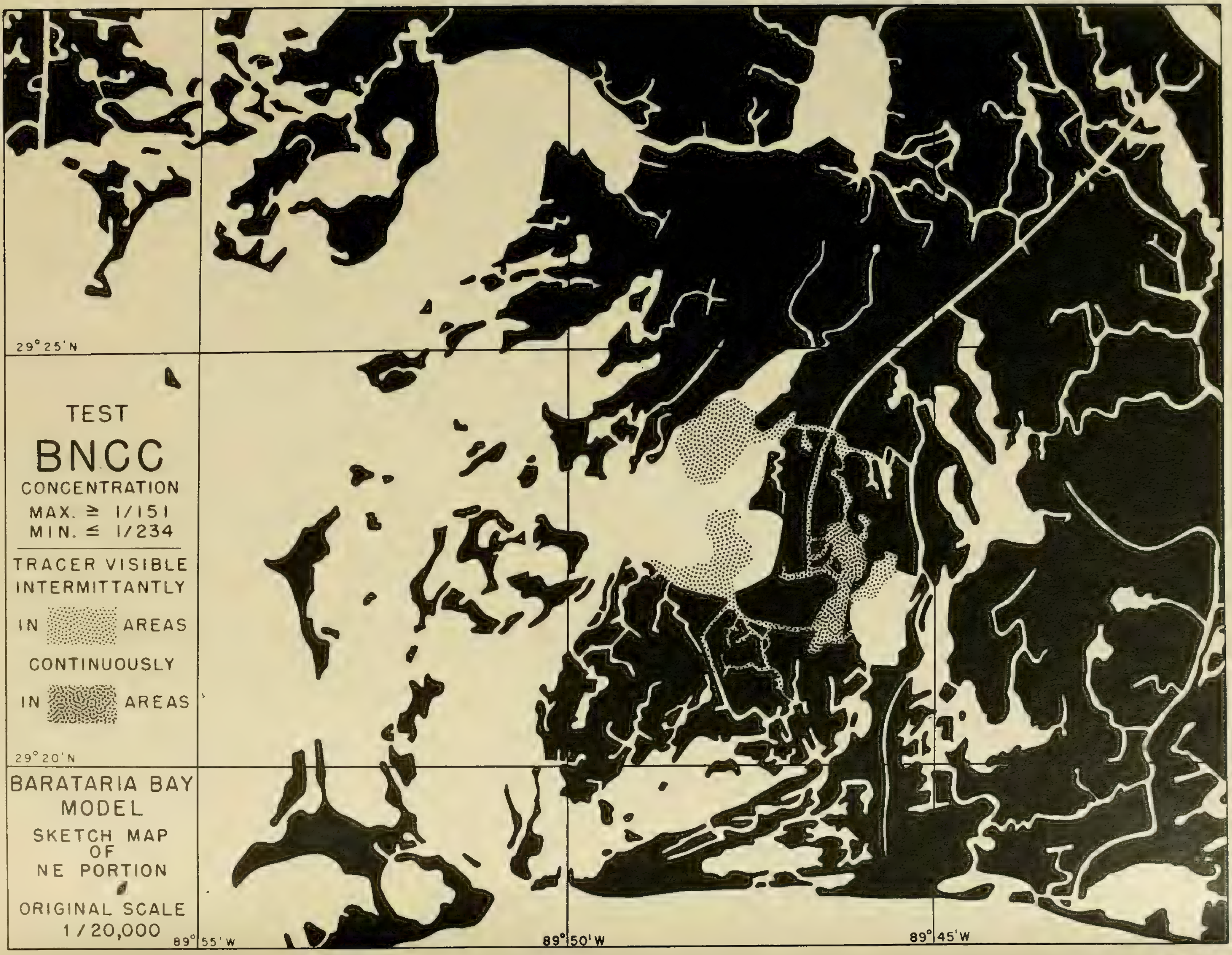
ORIGINAL SCALE
1/20,000

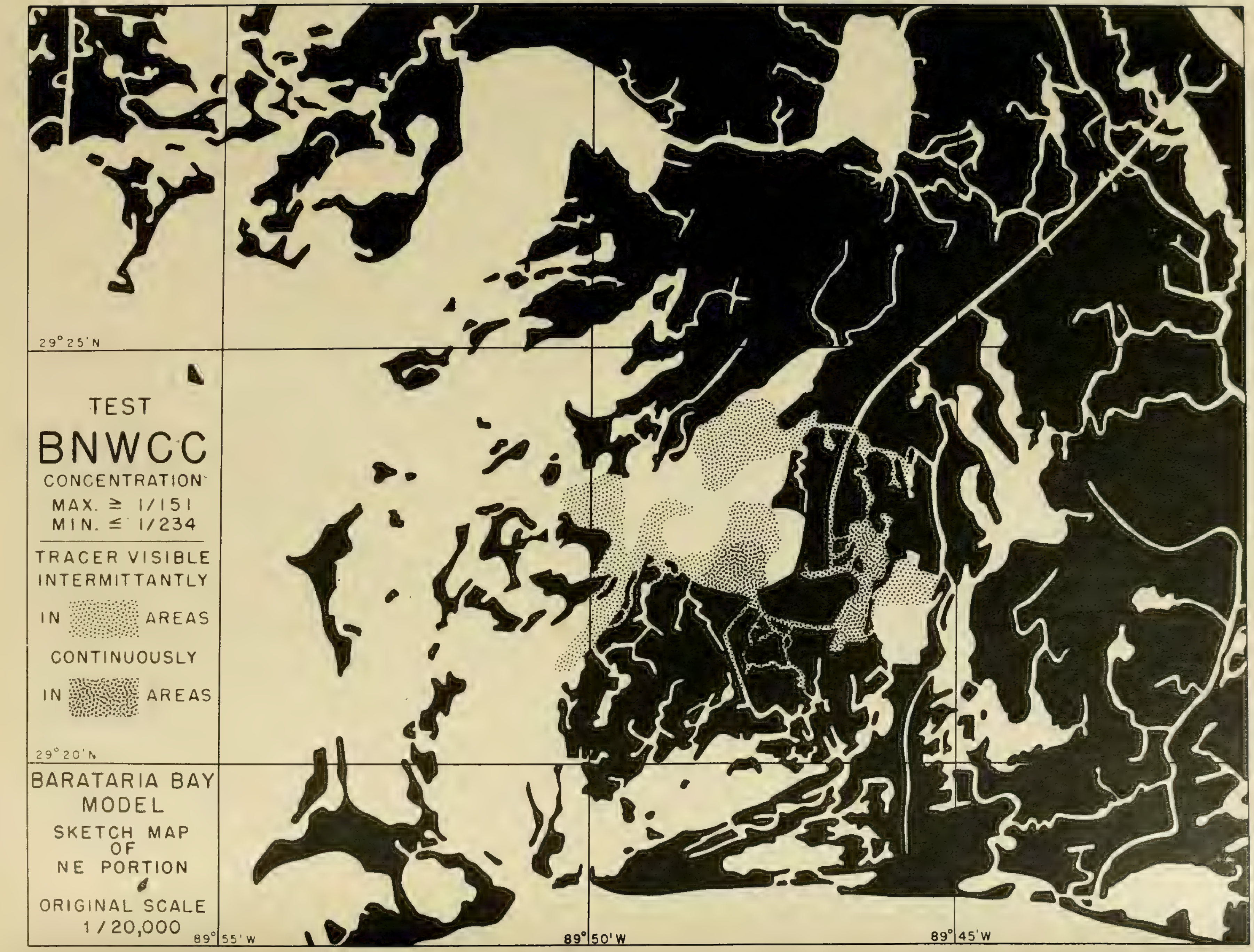

29°25'N
TEST
BOCC
CONCENTRATION
MAX. ≥ 1/151
MIN. ≤ 1/234
TRACER VISIBLE
INTERMITTANTLY
IN ░ AREAS
CONTINUOUSLY
IN ▒ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W

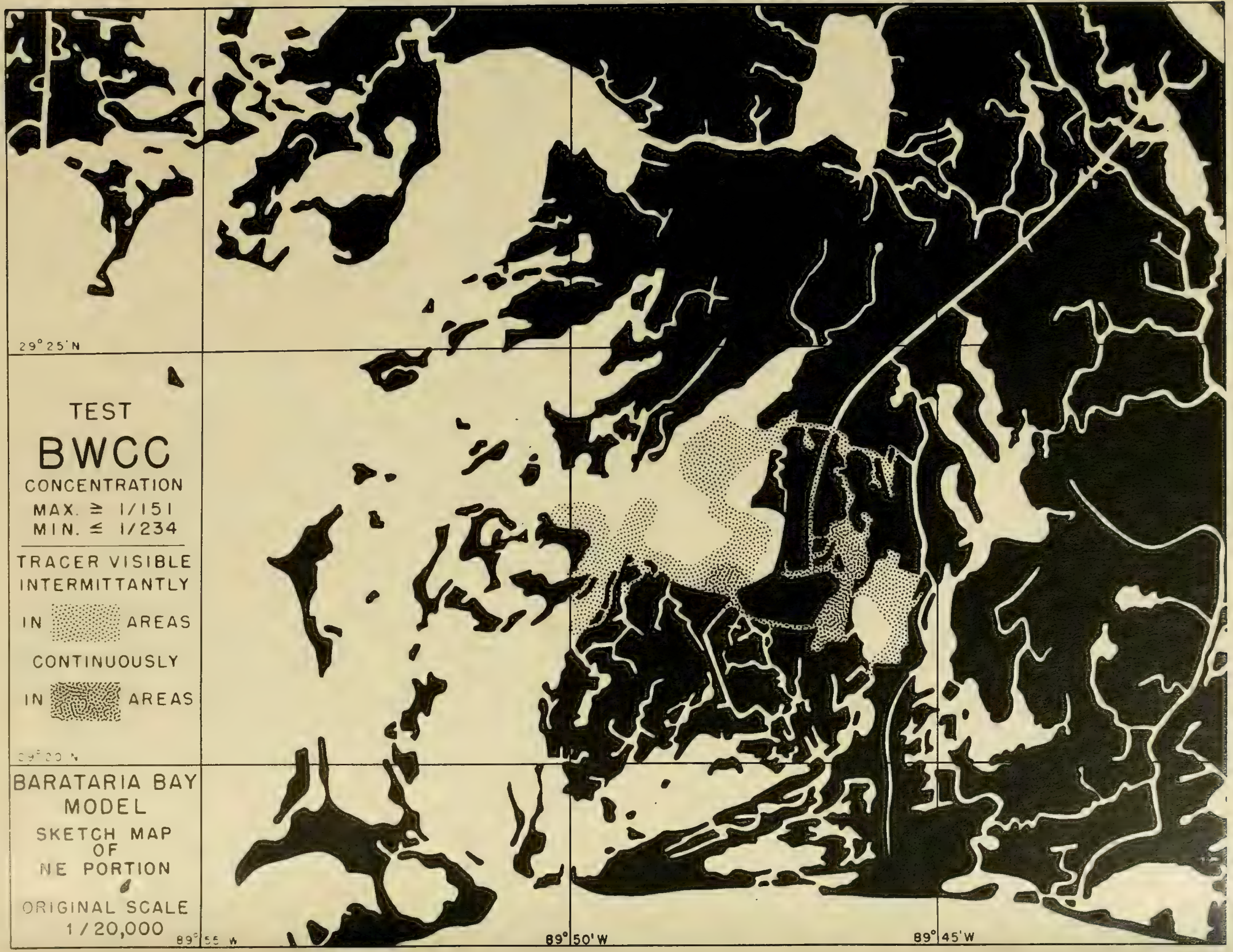

29°25'N
TEST
BSRCC
CONCENTRATION
MAX. ≥ 1/151
MIN. ≤ 1/234
TRACER VISIBLE
INTERMITTANTLY
IN ░ AREAS
CONTINUOUSLY
IN ▓ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W

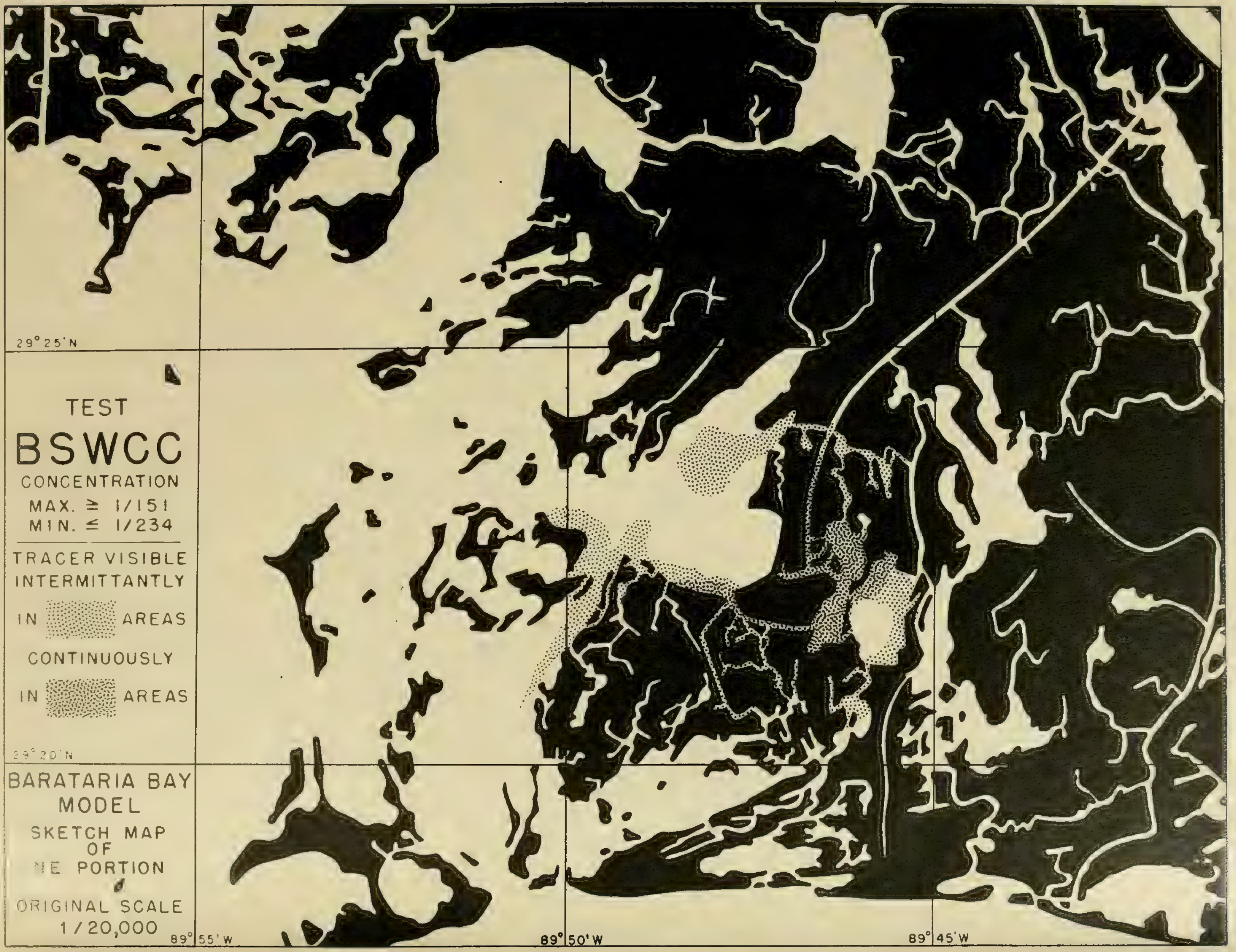

29°25'N
TEST
BWRCC
CONCENTRATION
MAX. ≥ 1/151
MIN. ≤ 1/234
TRACER VISIBLE
INTERMITTANTLY
IN ▒ AREAS
CONTINUOUSLY
IN ▓ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W

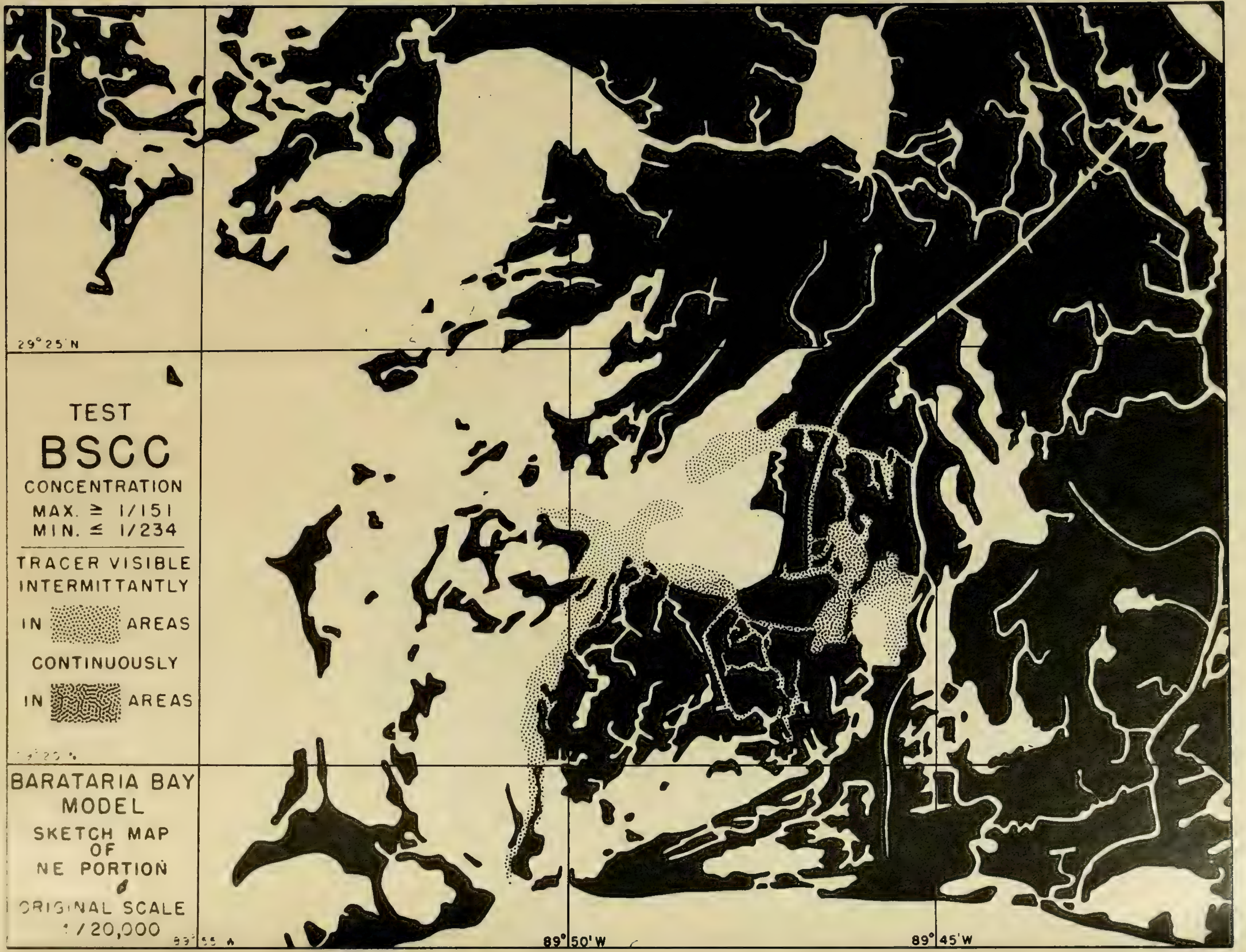

29° 25' N
TEST
BNECC
CONCENTRATION
MAX. ≥ 1/151
MIN. ≤ 1/234
TRACER VISIBLE
INTERMITTANTLY
IN AREAS
CONTINUOUSLY
IN AREAS
29° 20' N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89° 55' W
89° 50' W
89° 45' W

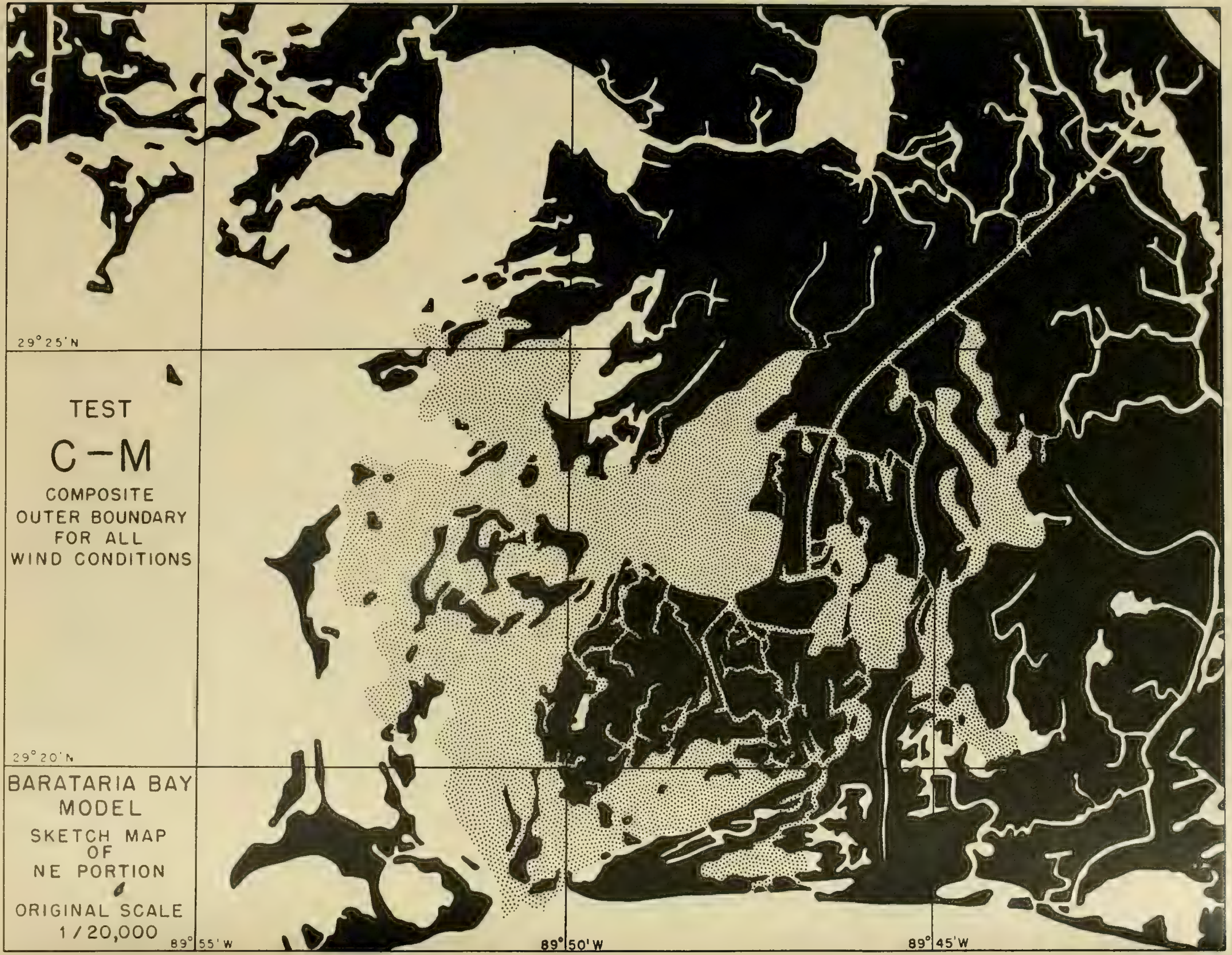

TEST
BNCC
CONCENTRATION
MAX. ≥ 1/151
MIN. ≤ 1/234
TRACER VISIBLE
INTERMITTANTLY
IN ▒ AREAS
CONTINUOUSLY
IN ▓ AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
29°25'N
29°20'N
89°55'W
89°50'W
89°45'W


29°25'N
TEST
BNWCC
CONCENTRATION
MAX. ≥ 1/151
MIN. ≤ 1/234
TRACER VISIBLE
INTERMITTANTLY
IN ░ AREAS
CONTINUOUSLY
IN ▓ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W


TEST
BWCC
CONCENTRATION
MAX. ≥ 1/151
MIN. ≤ 1/234
TRACER VISIBLE
INTERMITTANTLY
IN AREAS
CONTINUOUSLY
IN AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
29°25'N
29°20'N
89°55'W
89°50'W
89°45'W


29°25'N
TEST
BSWCC
CONCENTRATION
MAX. ≥ 1/151
MIN. ≤ 1/234
TRACER VISIBLE
INTERMITTANTLY
IN ░ AREAS
CONTINUOUSLY
IN ▒ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W


29°25'N
TEST
BSCC
CONCENTRATION
MAX. ≥ 1/151
MIN. ≤ 1/234
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W



TEST

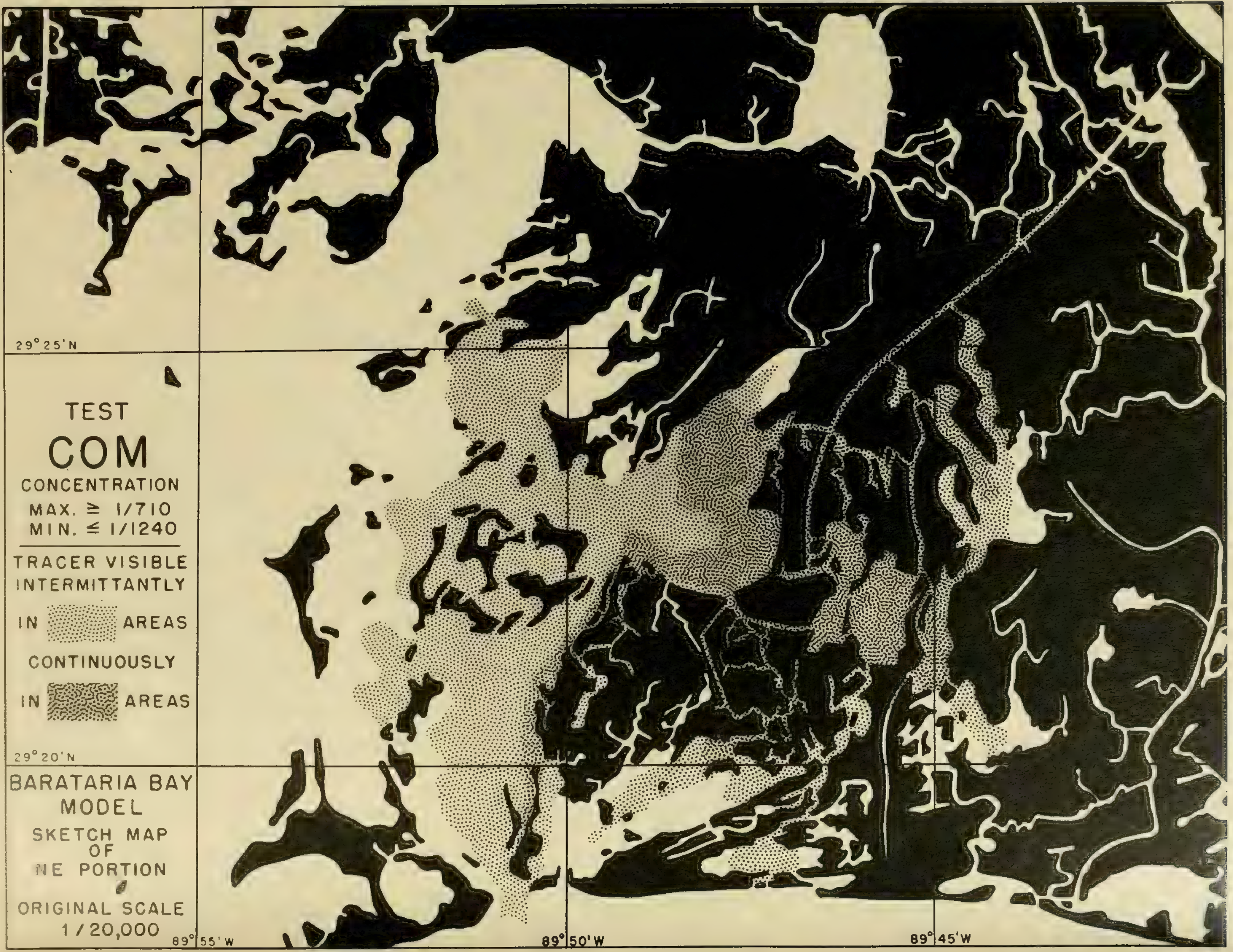
C—M

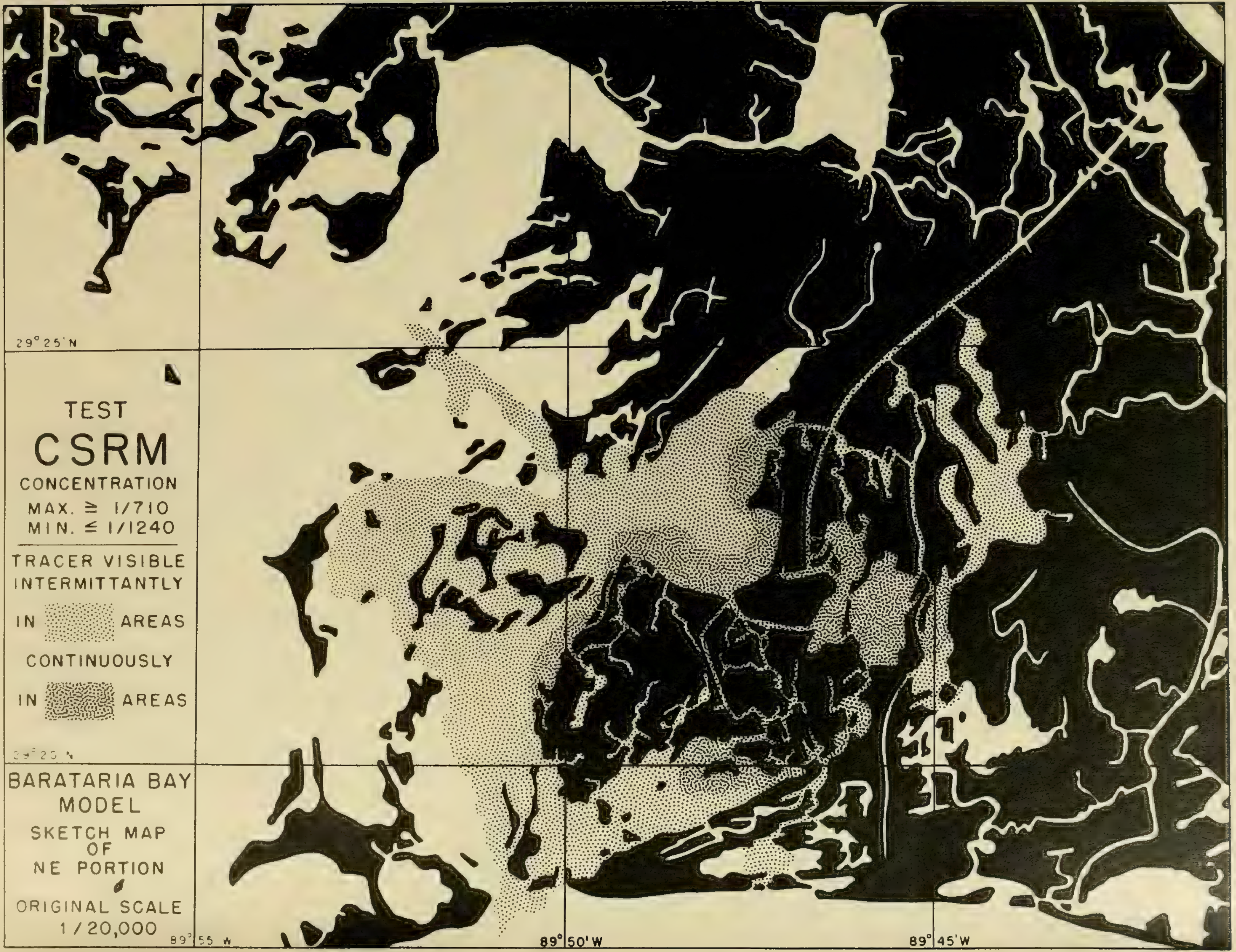
COMPOSITE
OUTER BOUNDARY
FOR ALL
WIND CONDITIONS

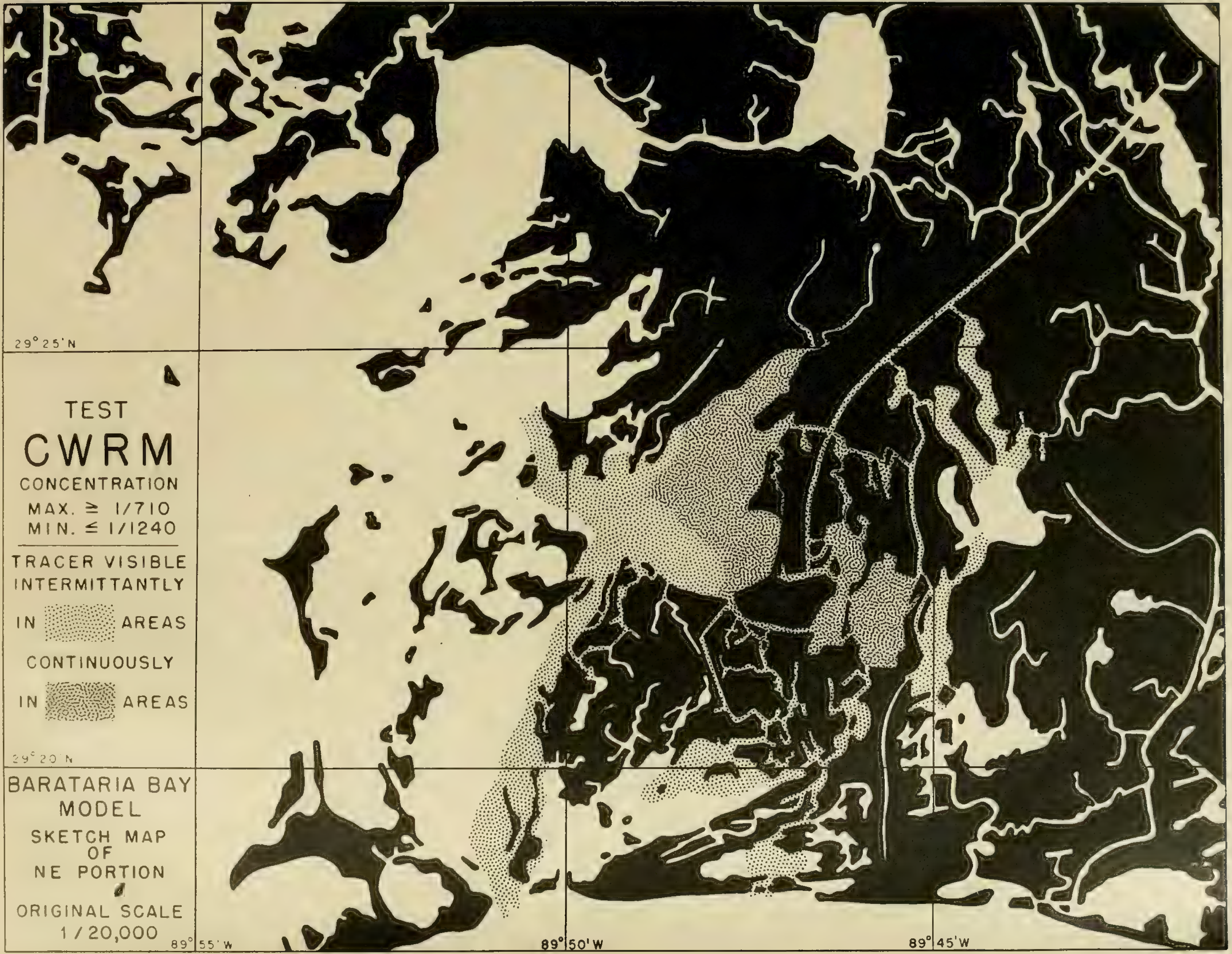
BARATARIA BAY
MODEL

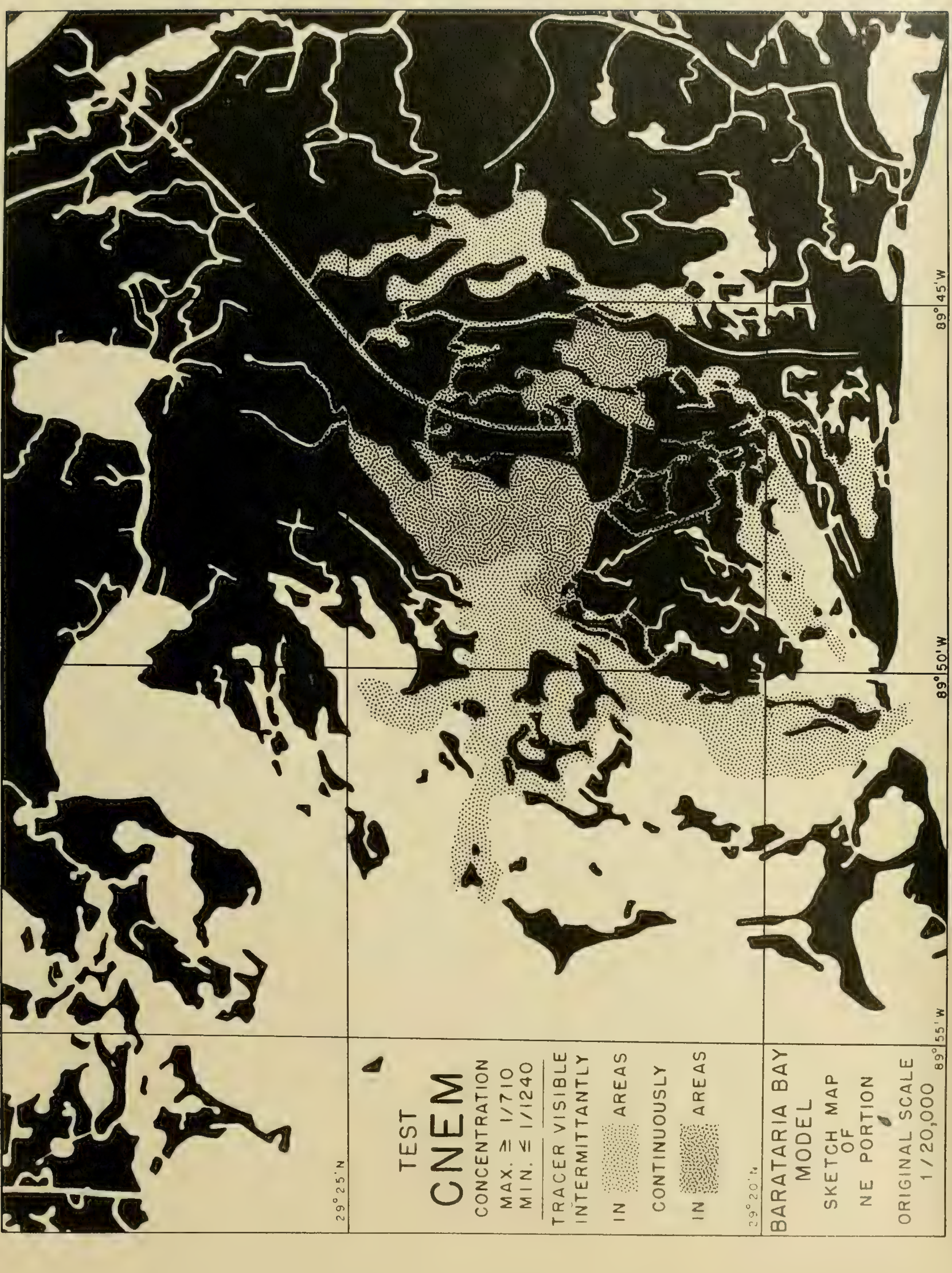
SKETCH MAP
OF
NE PORTION

ORIGINAL SCALE
1/20,000


29°25'N
TEST
COM
CONCENTRATION
MAX. ≧ 1/710
MIN. ≦ 1/1240
TRACER VISIBLE
INTERMITTANTLY
IN ▒ AREAS
CONTINUOUSLY
IN ▓ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W


29°25'N
TEST
CSRM
CONCENTRATION
MAX. ≥ 1/710
MIN. ≤ 1/1240
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W


29°25'N
TEST
CWRM
CONCENTRATION
MAX. ≥ 1/710
MIN. ≤ 1/1240
TRACER VISIBLE
INTERMITTANTLY
IN ░ AREAS
CONTINUOUSLY
IN ▒ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W



TEST

CNEM

CONCENTRATION

MAX. ≥ 1/710

MIN. ≤ 1/1240

TRACER VISIBLE

INTERMITTANTLY

IN ░ AREAS

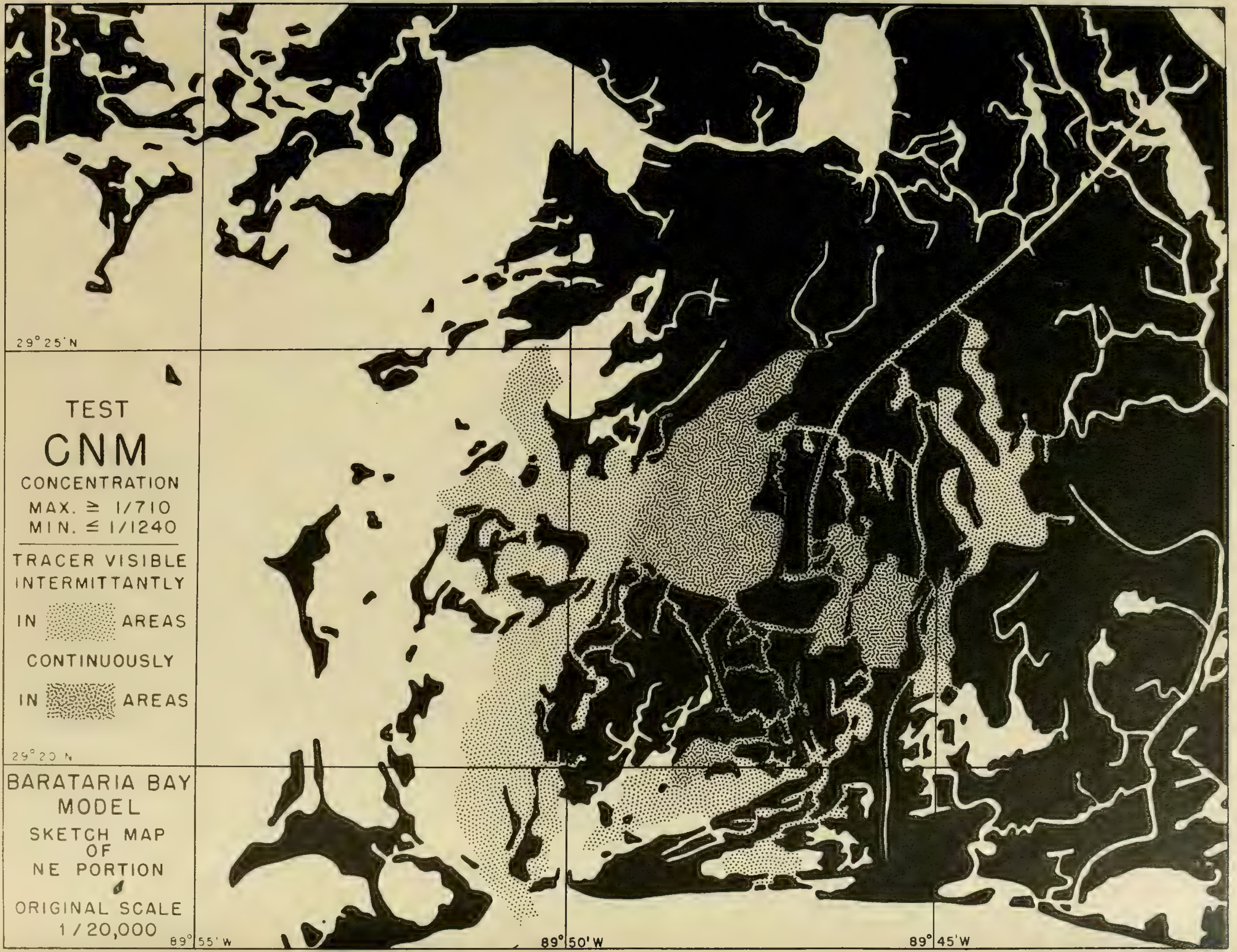
CONTINUOUSLY

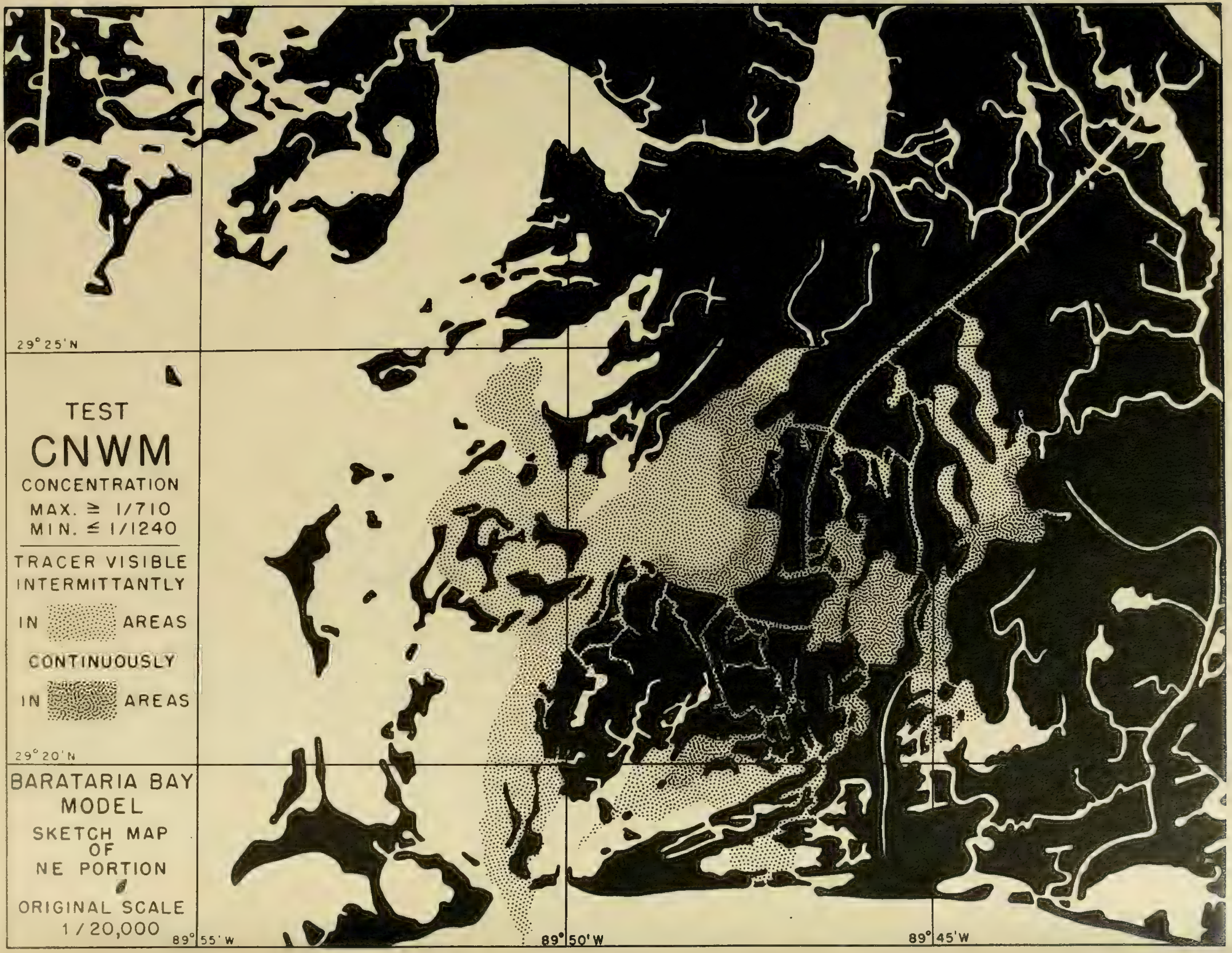
IN ▒ AREAS

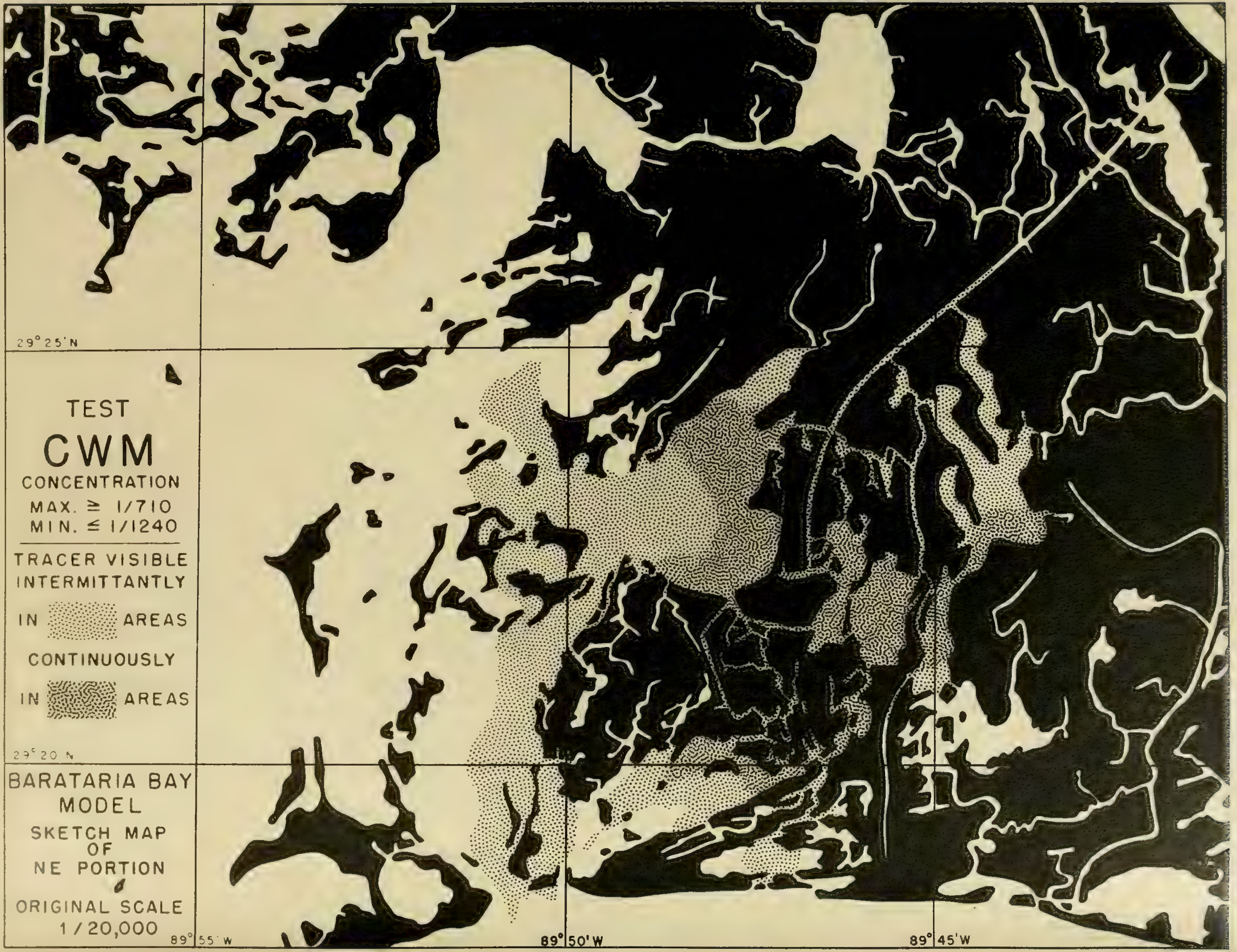
BARATARIA BAY MODEL

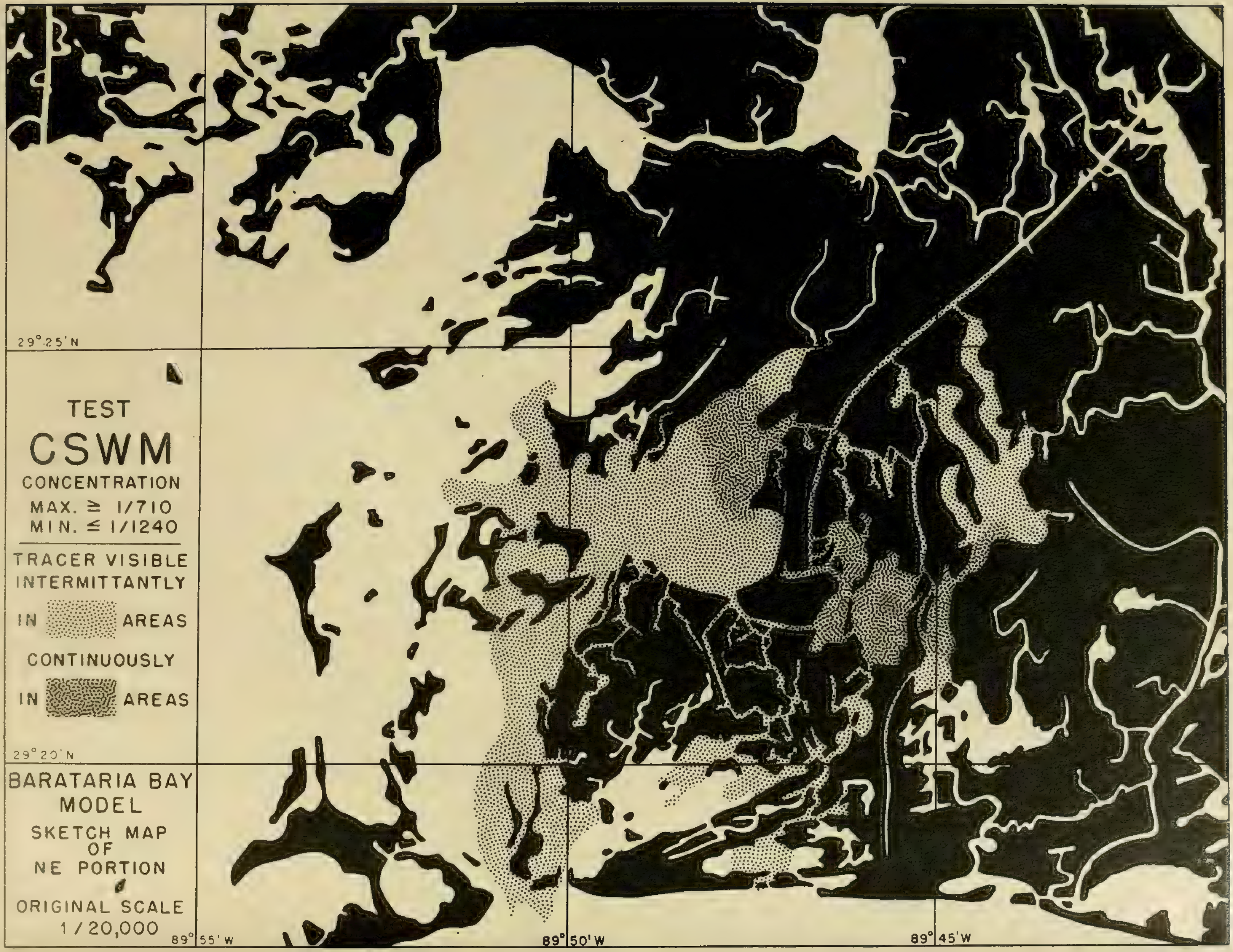
SKETCH MAP OF NE PORTION

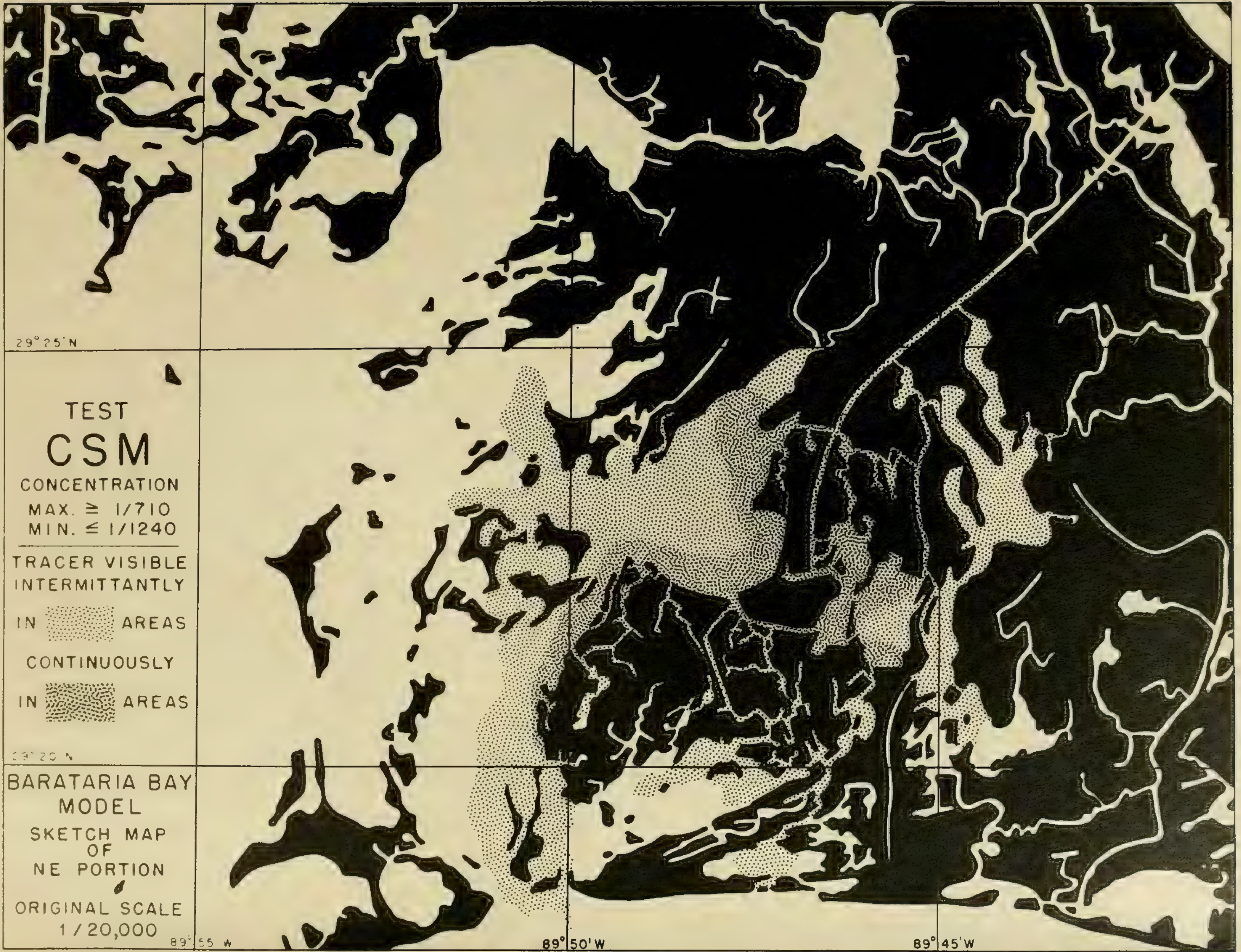
ORIGINAL SCALE 1/20,000


TEST
CNM
CONCENTRATION
MAX. ≥ 1/710
MIN. ≤ 1/1240
TRACER VISIBLE
INTERMITTANTLY
IN ░ AREAS
CONTINUOUSLY
IN ▓ AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
29°25'N
29°20'N
89°55'W
89°50'W
89°45'W


29°25'N
TEST
CNWM
CONCENTRATION
MAX. ≥ 1/710
MIN. ≤ 1/1240
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W


TEST
CWM
CONCENTRATION
MAX. ≥ 1/710
MIN. ≤ 1/1240
TRACER VISIBLE
INTERMITTANTLY
IN AREAS
CONTINUOUSLY
IN AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
29°25'N
29°20'N
89°55'W
89°50'W
89°45'W


29°25'N
TEST
CSWM
CONCENTRATION
MAX. ≥ 1/710
MIN. ≤ 1/1240
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1 / 20,000
89°55'W
89°50'W
89°45'W



TEST

CSM

CONCENTRATION

MAX. ≥ 1/710

MIN. ≤ 1/1240

TRACER VISIBLE
INTERMITTANTLY

IN ▒ AREAS

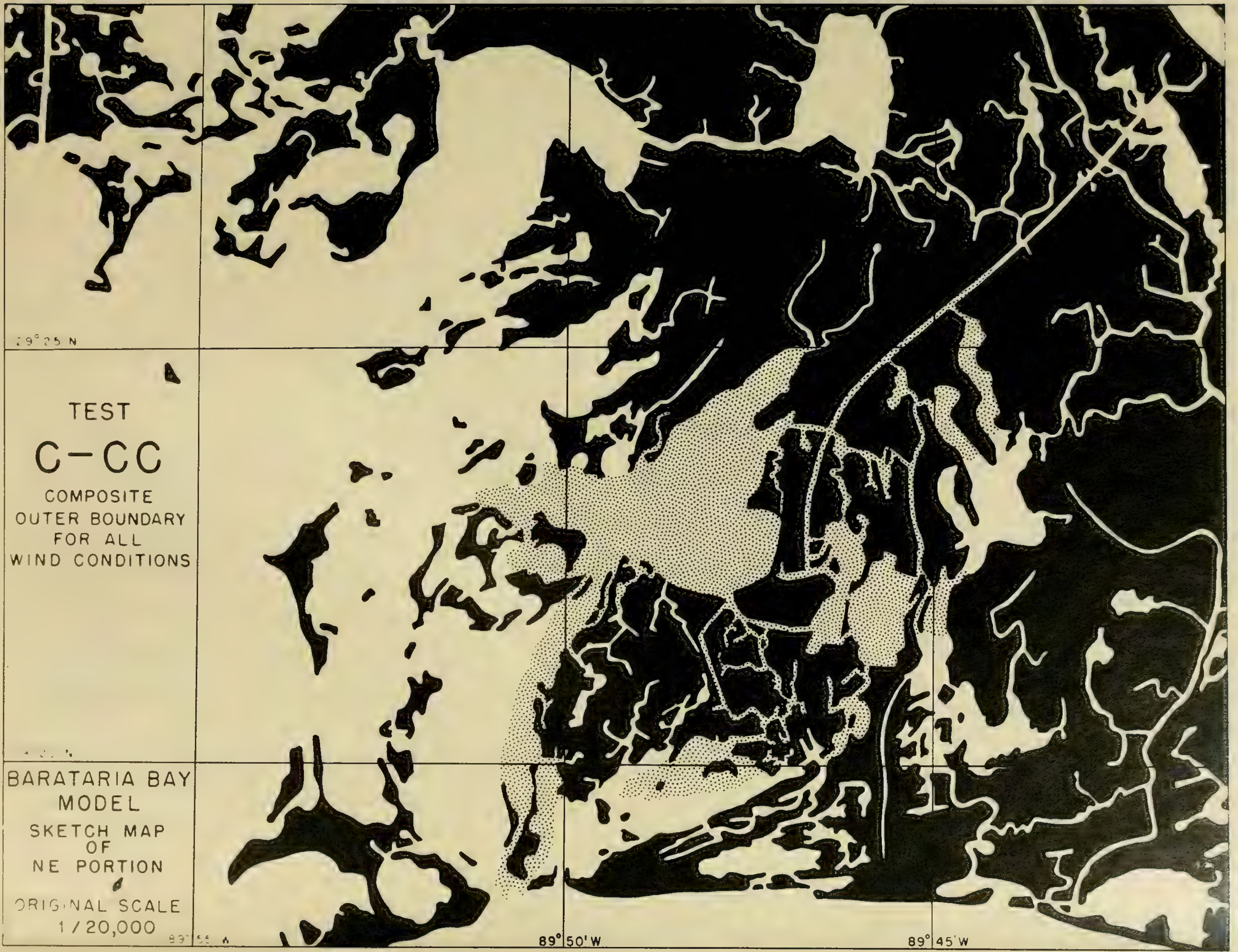
CONTINUOUSLY

IN ▓ AREAS

BARATARIA BAY
MODEL

SKETCH MAP
OF
NE PORTION

ORIGINAL SCALE
1/20,000



TEST

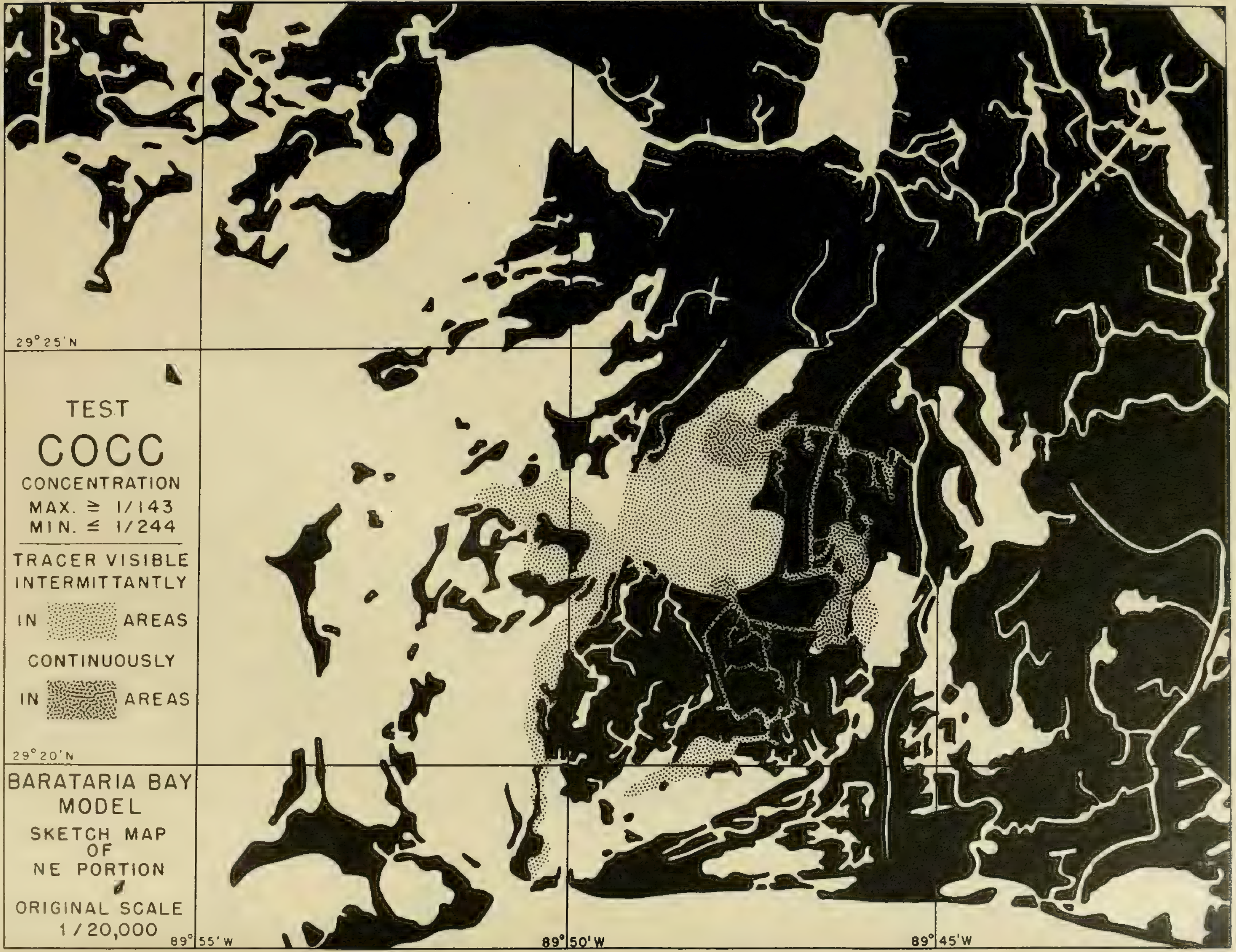
C–CC

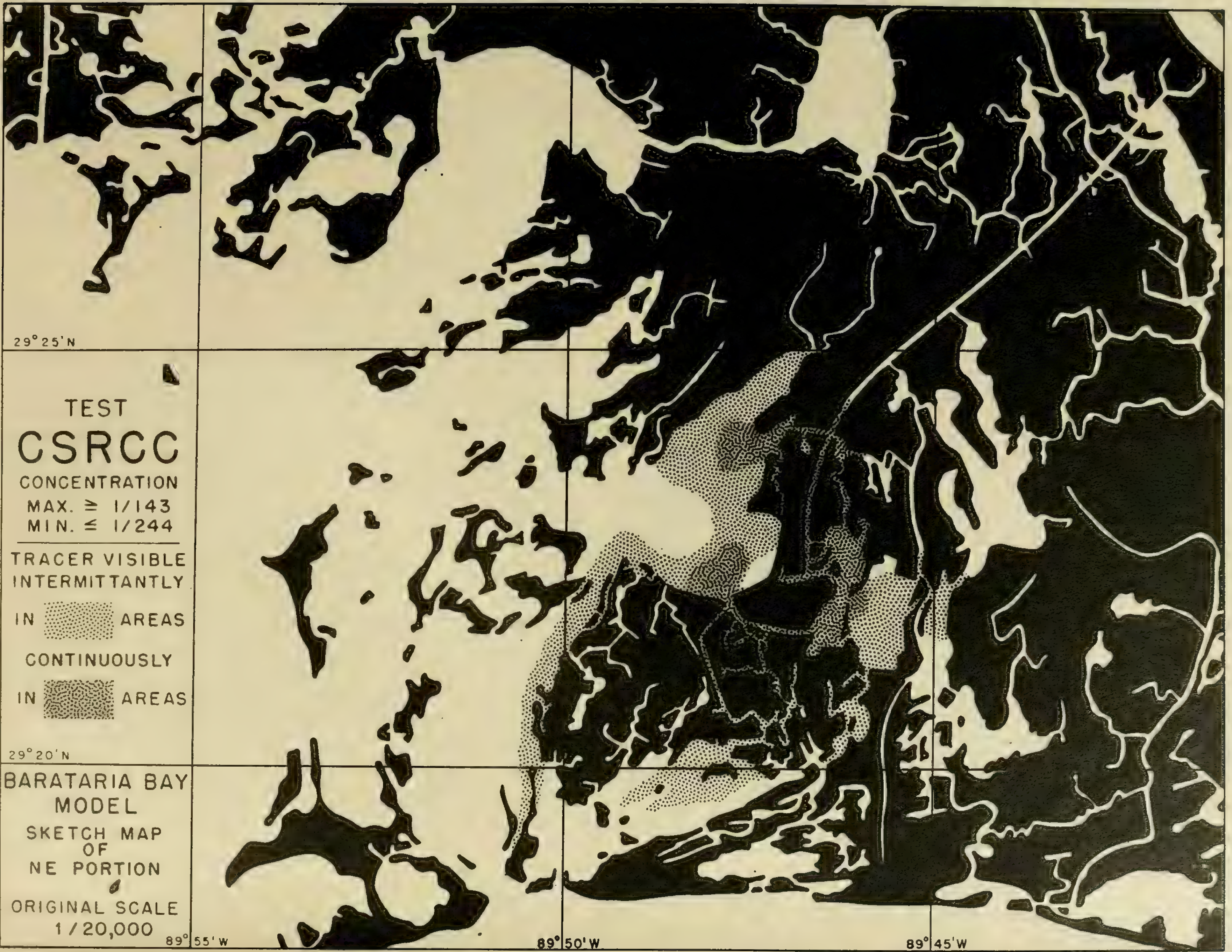
COMPOSITE
OUTER BOUNDARY
FOR ALL
WIND CONDITIONS

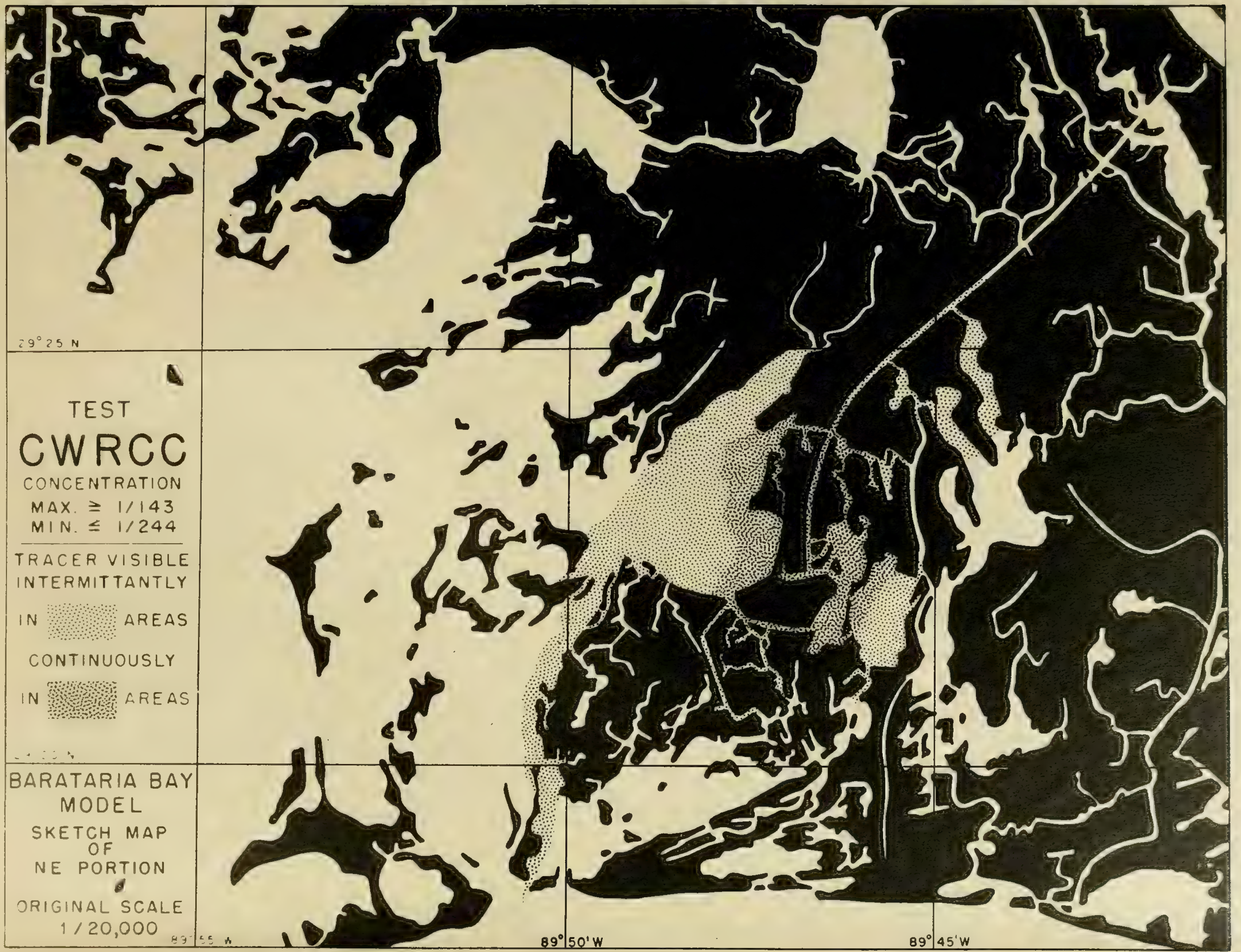
BARATARIA BAY
MODEL

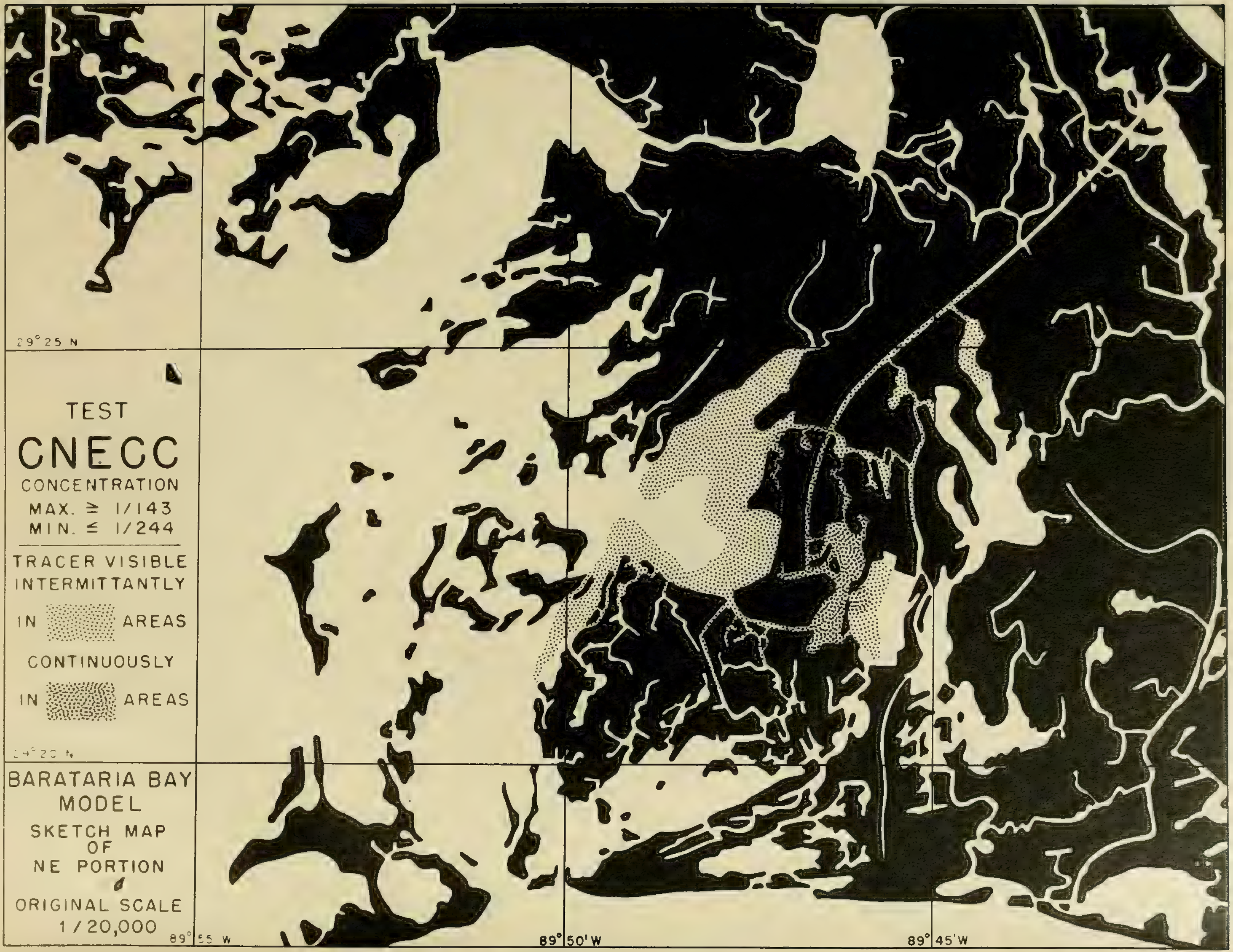
SKETCH MAP
OF
NE PORTION

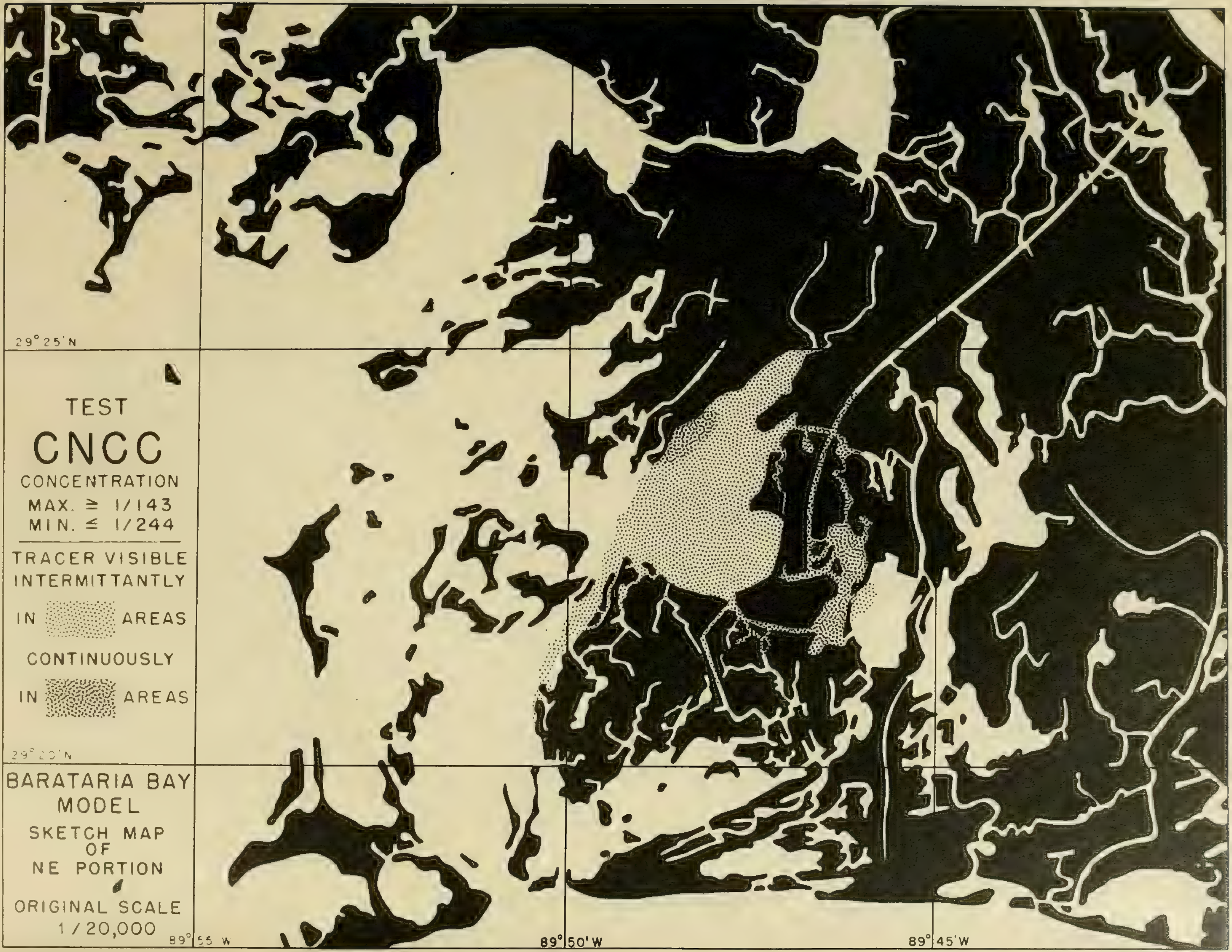
ORIGINAL SCALE
1/20,000

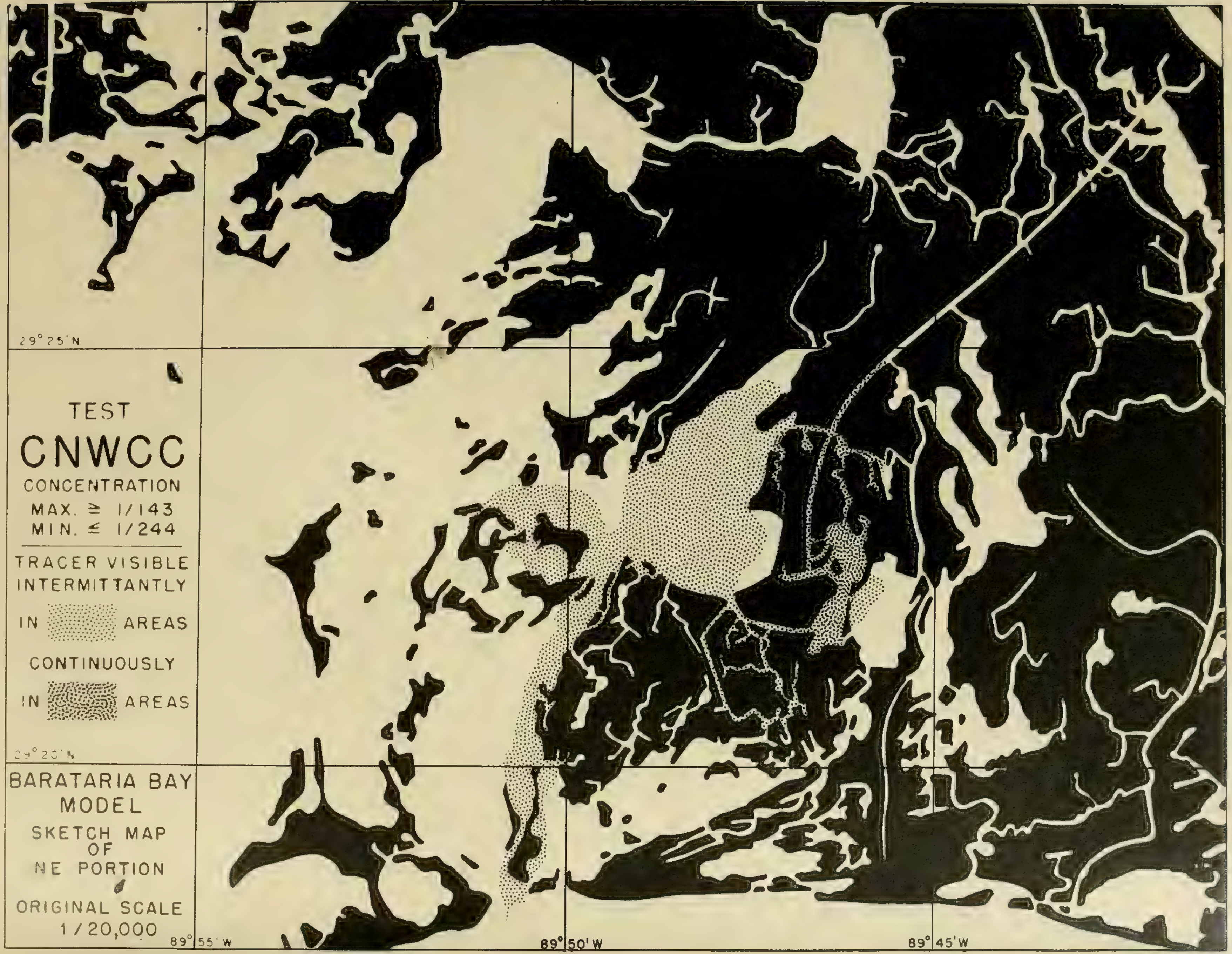

29°25'N
TEST
COCC
CONCENTRATION
MAX. ≥ 1/143
MIN. ≤ 1/244
TRACER VISIBLE
INTERMITTANTLY
IN ▒ AREAS
CONTINUOUSLY
IN ▓ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W

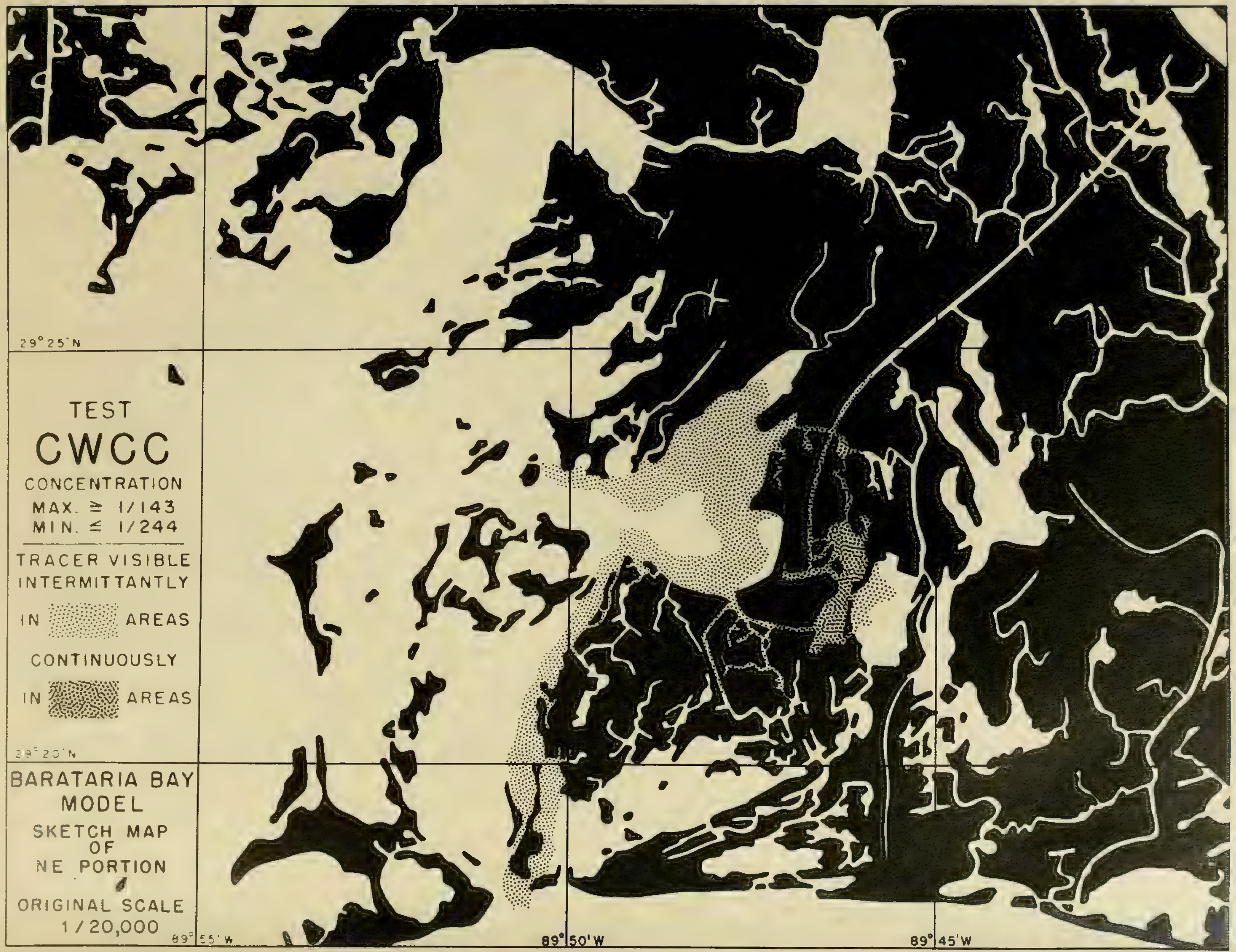

29°25'N
TEST
CSRCC
CONCENTRATION
MAX. ≥ 1/143
MIN. ≤ 1/244
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W

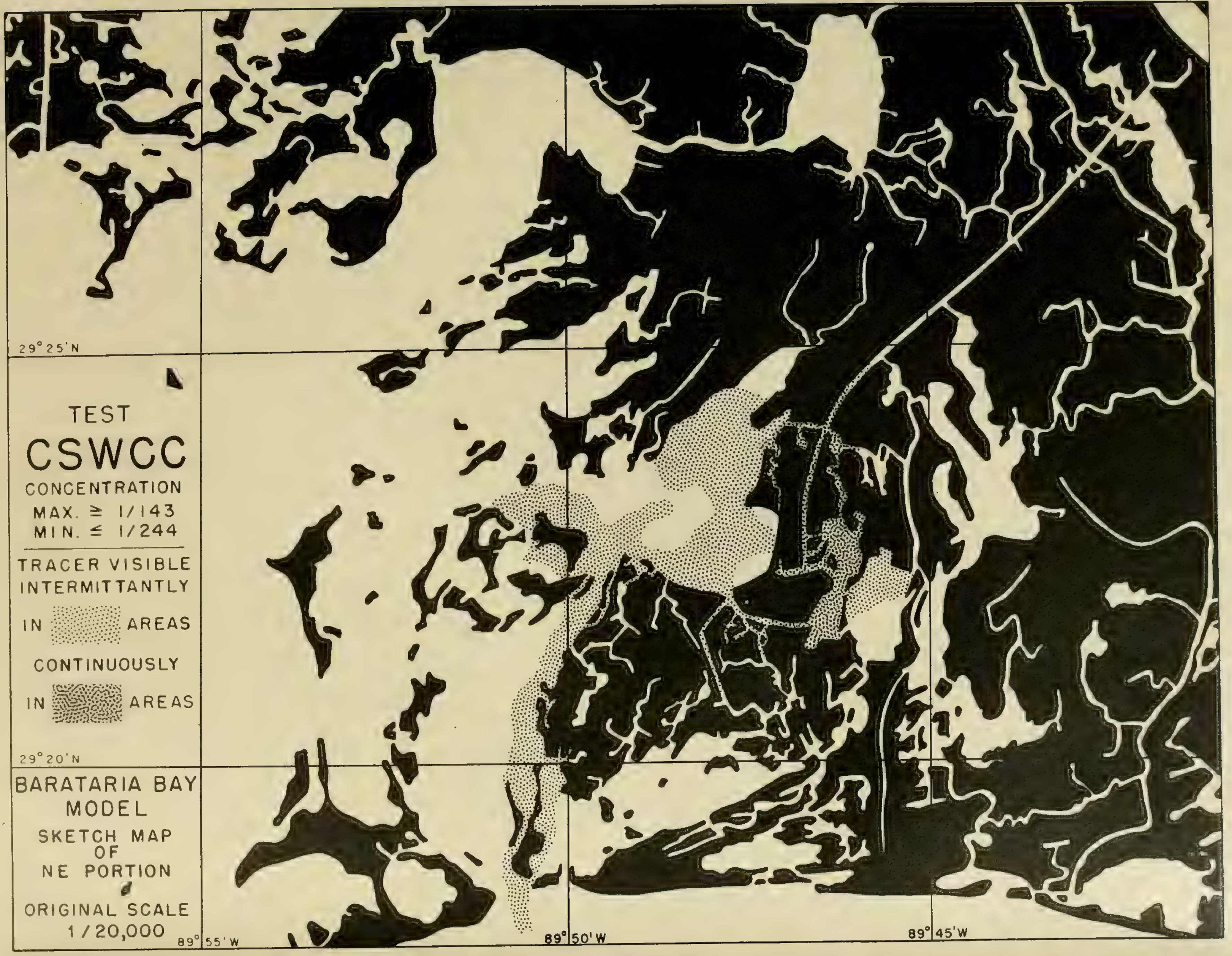

29°25 N
TEST
CWRCC
CONCENTRATION
MAX. ≥ 1/143
MIN. ≤ 1/244
TRACER VISIBLE
INTERMITTANTLY
IN ▒ AREAS
CONTINUOUSLY
IN ▓ AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55 W
89°50'W
89°45'W

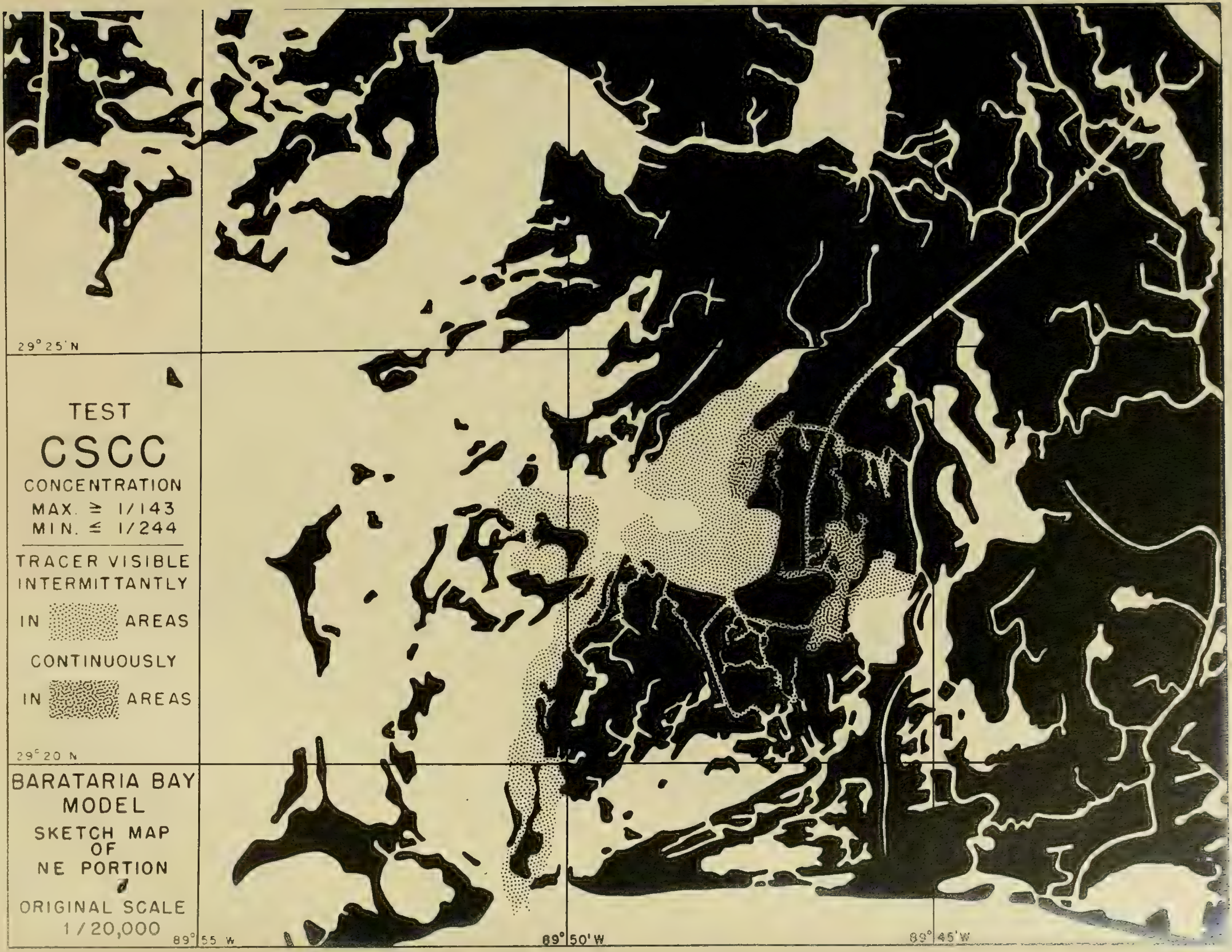

29°25 N
TEST
CNECC
CONCENTRATION
MAX. ≥ 1/143
MIN. ≤ 1/244
TRACER VISIBLE
INTERMITTANTLY
IN ░ AREAS
CONTINUOUSLY
IN ▒ AREAS
29°20 N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55 W
89°50'W
89°45'W


29°25'N
TEST
CNCC
CONCENTRATION
MAX. ≥ 1/143
MIN. ≤ 1/244
TRACER VISIBLE
INTERMITTANTLY
IN ░ AREAS
CONTINUOUSLY
IN ▒ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W


TEST
CNWCC
CONCENTRATION
MAX. ≥ 1/143
MIN. ≤ 1/244
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
29°25'N
29°20'N
89°55'W
89°50'W
89°45'W


29°25'N
TEST
CWCC
CONCENTRATION
MAX. ≧ 1/143
MIN. ≦ 1/244
TRACER VISIBLE
INTERMITTANTLY
IN AREAS
CONTINUOUSLY
IN AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W


29°25'N
TEST
CSWCC
CONCENTRATION
MAX. ≥ 1/143
MIN. ≤ 1/244
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
29°20'N
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
89°55'W
89°50'W
89°45'W


TEST
CSCC
CONCENTRATION
MAX. ≥ 1/143
MIN. ≤ 1/244
TRACER VISIBLE
INTERMITTANTLY
IN ▨ AREAS
CONTINUOUSLY
IN ▩ AREAS
BARATARIA BAY
MODEL
SKETCH MAP
OF
NE PORTION
ORIGINAL SCALE
1/20,000
29° 25' N
29° 20' N
89° 55' W
89° 50' W
89° 45' W

MBL/WHOI